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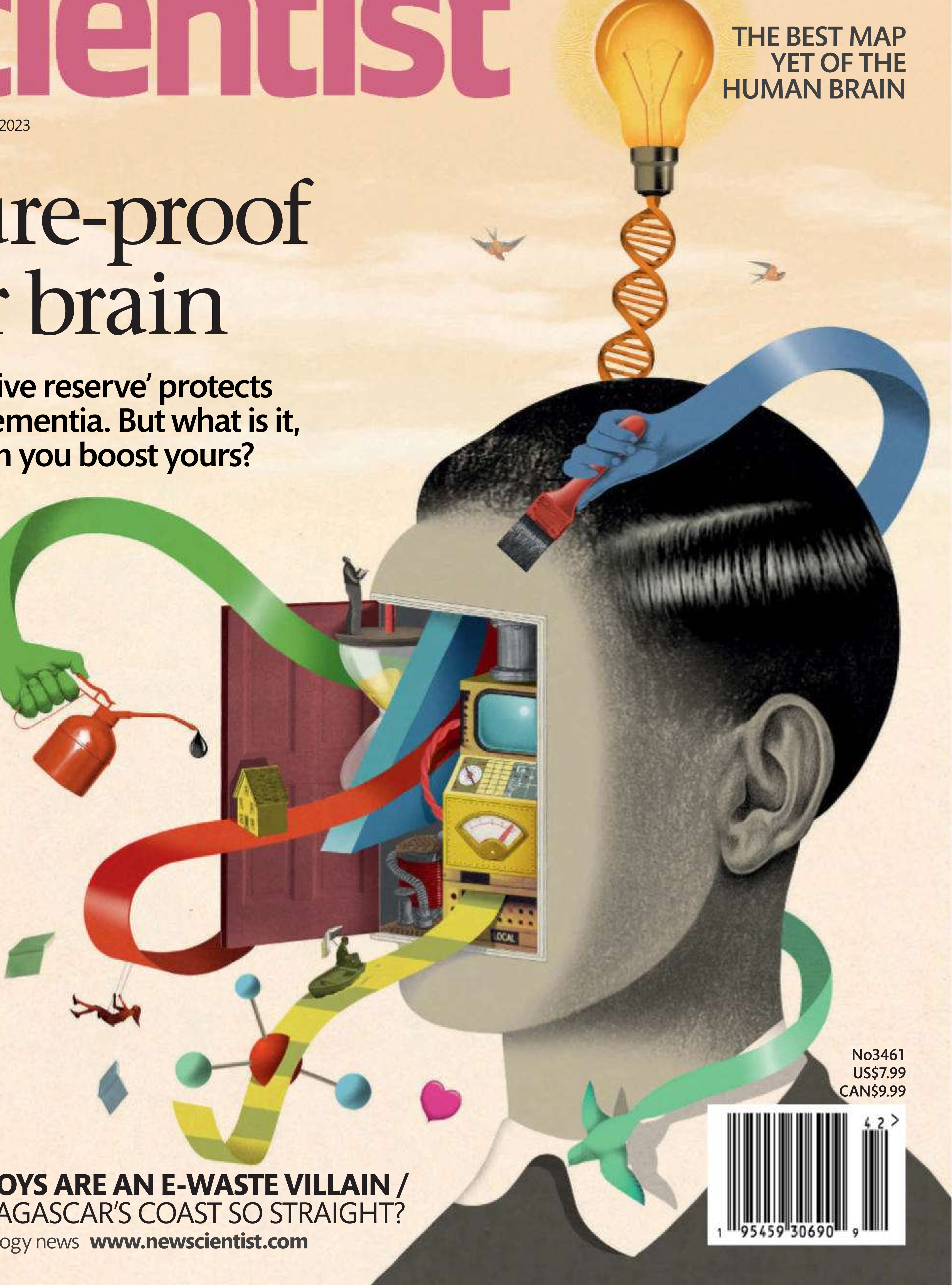

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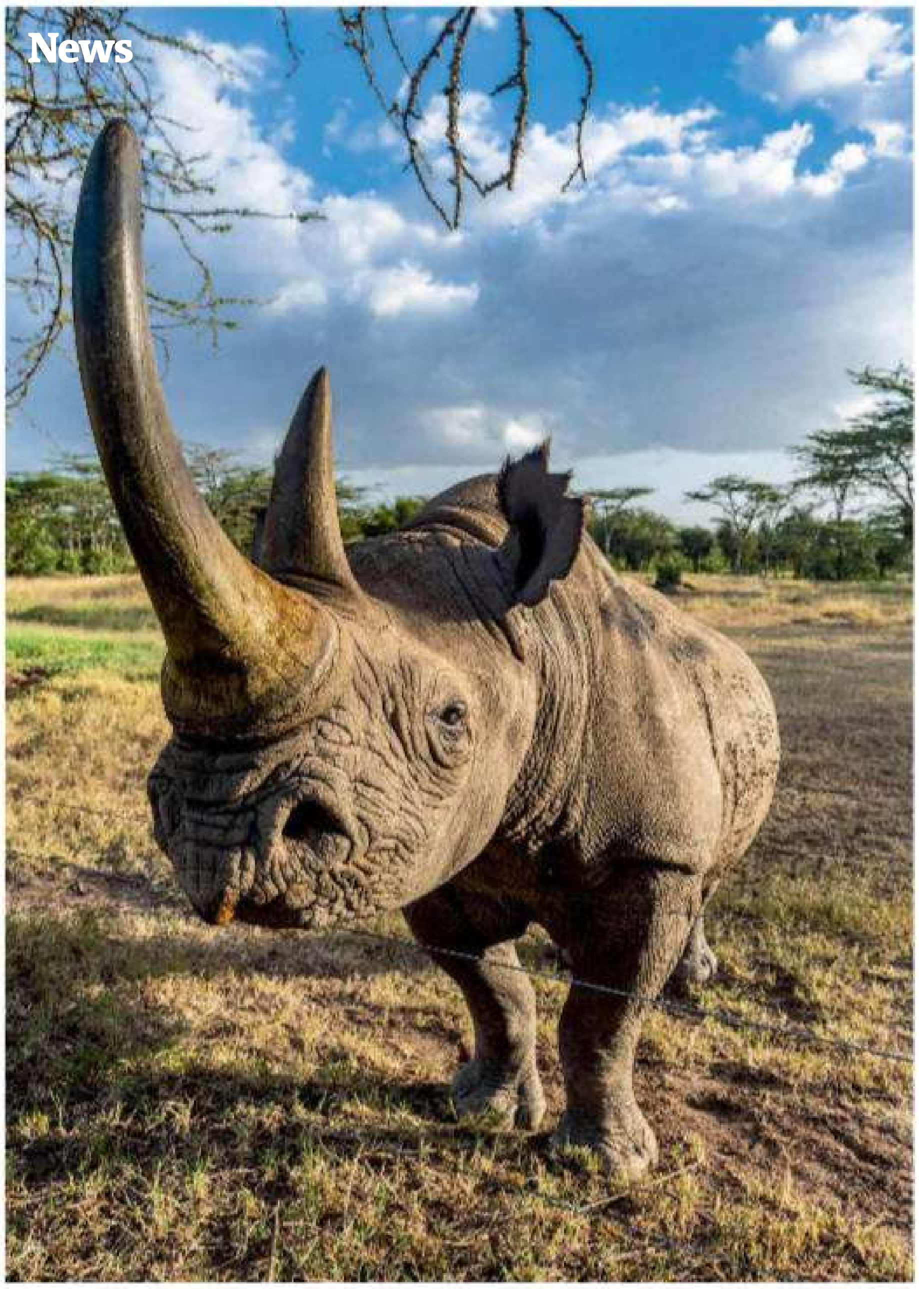

MICHAEL RUNKEL/ROBERTHARDING/ALAMY

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Instant Expert

The quantum world

Does anyone understand quantum theory? The legendary Richard Feynman suggested that if you think you do, you haven't understood it at all. Join six expert speakers in London on 28 October to hear about the coming revolution in quantum technologies. Plus, find out how quantum mechanics plays a deep role in biological processes and sits at the core of our current best theory of the cosmos.

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Tour

Wildlife conservation of Sri Lanka

Go in search of leopards and forest elephants, as well as more unusual species like sloth bears, pangolins and lorises. Visit a turtle conservation centre in Rekawa village and be inspired by Kanneliya rainforest, then go blue whale watching with an expert marine biologist. This 12-day tour starts on 18 March 2024 and costs £3999.

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Podcast

Weekly

The team discuss a dramatic clash of ice giants in a solar system far from ours and reveal the most detailed brain atlas to date, describing thousands of cell types. Find out why the US National Security Agency has been accused of allowing backdoors into future methods for securing data. Plus, how Earth's solid core manages to be so surprisingly squishy.

newscientist.com/nspod

MITSUAKI IWAGO/MINDEN PICTURES/ALAMY

Slender loris Visit Sri Lanka's wild hotspots on a conservation tour

MARK BLOWER

Imaging abstractions Hiroshi Sugimoto depicts mathematics

Video

Photographic reflection

A retrospective of key works by renowned photographer Hiroshi Sugimoto has opened at London's Hayward Gallery. It includes his latest project, Opticks, which reimagines Isaac Newton's seminal treatise of the same name. "I'm just borrowing many, many important scientists' experiences to be studied again, and see where I can go from there," he says.

youtube.com/newscientist

Newsletter

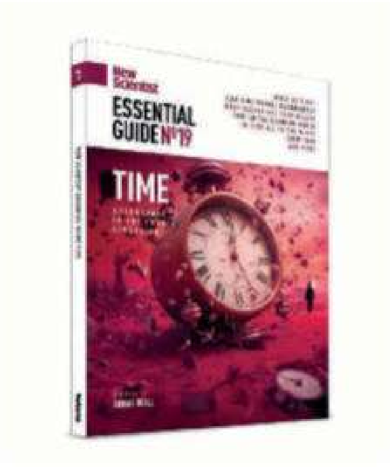
Wild Wild Life

Humans understand that sex makes babies. But it presumably required careful observation, deep thinking and language for ancient people to make that link. Given that no other species has our capacity for language or abstract reasoning, Colin Barras asks: do any other species know where babies come from?

newscientist.com/ wild-wild-life

Newsletter

> **"A male lion lacks the mental capacity to understand if he is the father of a cub"**



Essential guide

Our lives are often governed by the familiar ticking of the clock, but where does this ticking come from? This *New Scientist Essential Guide* explores why time is the fundamental facet of our existence. Available to download in the *New Scientist* app or to purchase in print from our shop.

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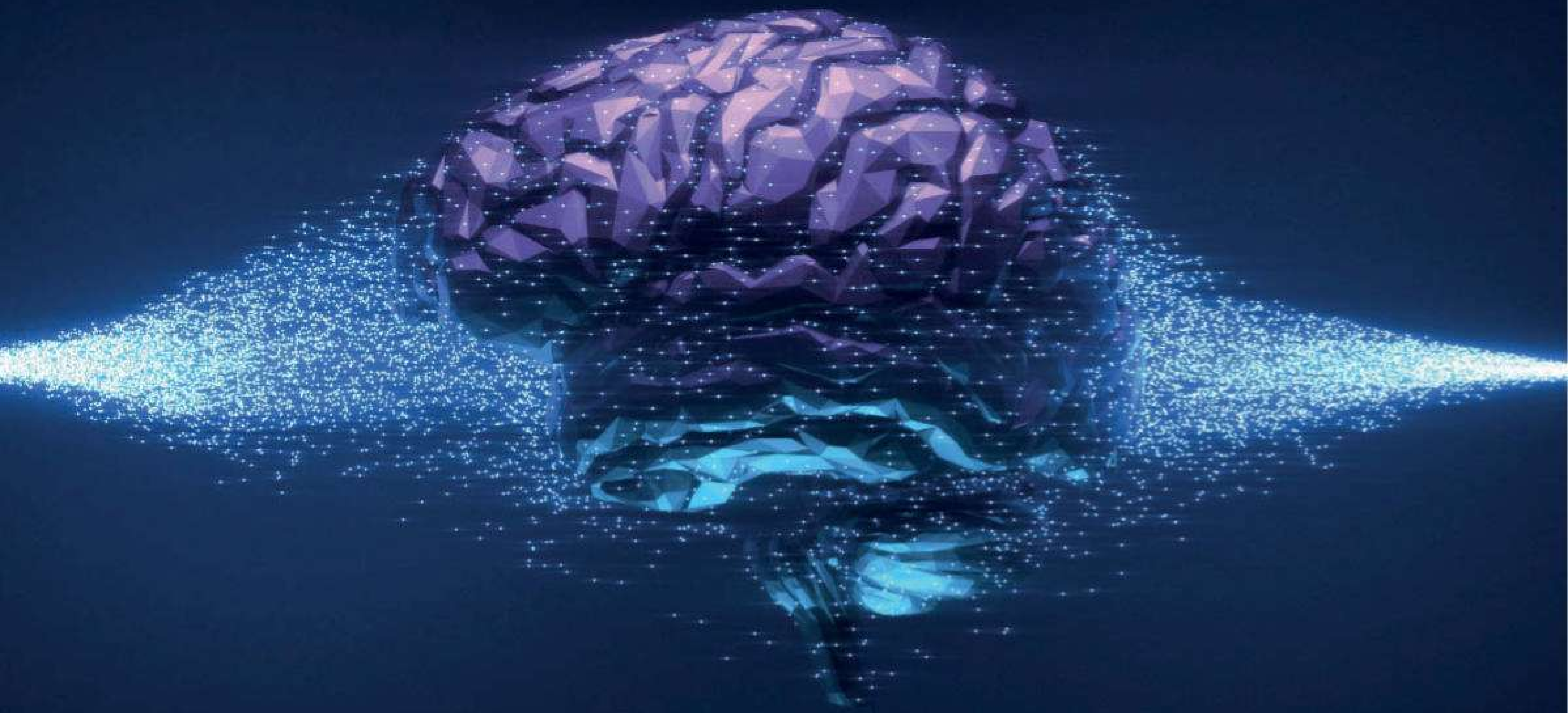

Online event

The road to conscious machines

7 November, 6 -7pm GMT, 1-2pm EST and on demand

Join Michael Wooldridge, a professor of computer science at the University of Oxford and a programme director for AI, as he brings a healthy injection of humility to an overhyped field and changes the prevailing narrative on AI. He will reveal how misguided anxieties distract us from the more immediate risks that this transformative technology poses – from algorithmic bias to fake news.

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The ultimate brain challenge

We can all build a better brain, but we are going to have to put in the work

THEY were considered flukes. Older people found upon their deaths to have brains full of the plaques and tangles associated with Alzheimer's disease, yet who had shown no signs of cognitive decline while alive. But then more cases appeared, and yet more. Something was protecting these people whose mental faculties remained bright, despite them facing the same destruction in their brain as others with memory loss, confusion and other symptoms of dementia.

As more brains were analysed, it was discovered that these cases aren't rare. Up to 30 per cent of older people have enough plaques and tangles to be diagnosed with Alzheimer's, but never show any outward symptoms of the condition.

What side we fall on seems to depend in part on an enigmatic concept known as "cognitive reserve". For years, we have only been able to refer to it by analogy. Some see it as a cushion of sorts, a barrier that slows the effect of damage. Others liken it to the building of bypasses – alternate pathways for information to flow through when normal routes are destroyed.

> "Mental engagement and challenging activities are key to building a 'cognitive reserve'"

Now, finally, we are on firmer ground. As we explore on page 30, fascinating new evidence has pinpointed the likely brain proteins and anatomical features involved in maintaining the cognitive reserve. It is a fascinating step in our understanding of how the human brain withstands ageing. It also presents opportunities to boost the brain. The normal suggestions are there, such as better sleep and more exercise. And, of course, there is hope for a drug that bolsters cognitive reserve. But what gives us pause is the discovery that strong mental engagement and challenging cognitive activities are key. Just as yoga can give you the flexibility to withstand stiffening of joints in your later years, mental workouts appear to give the brain a flexibility that mitigates future damage.

Moreover, this seems to help at any age, overturning long-held assumptions that brain-boosting behaviour is a privilege of youth. This means there should be something each of us can do to build a better brain. It may just take some effort. ▮

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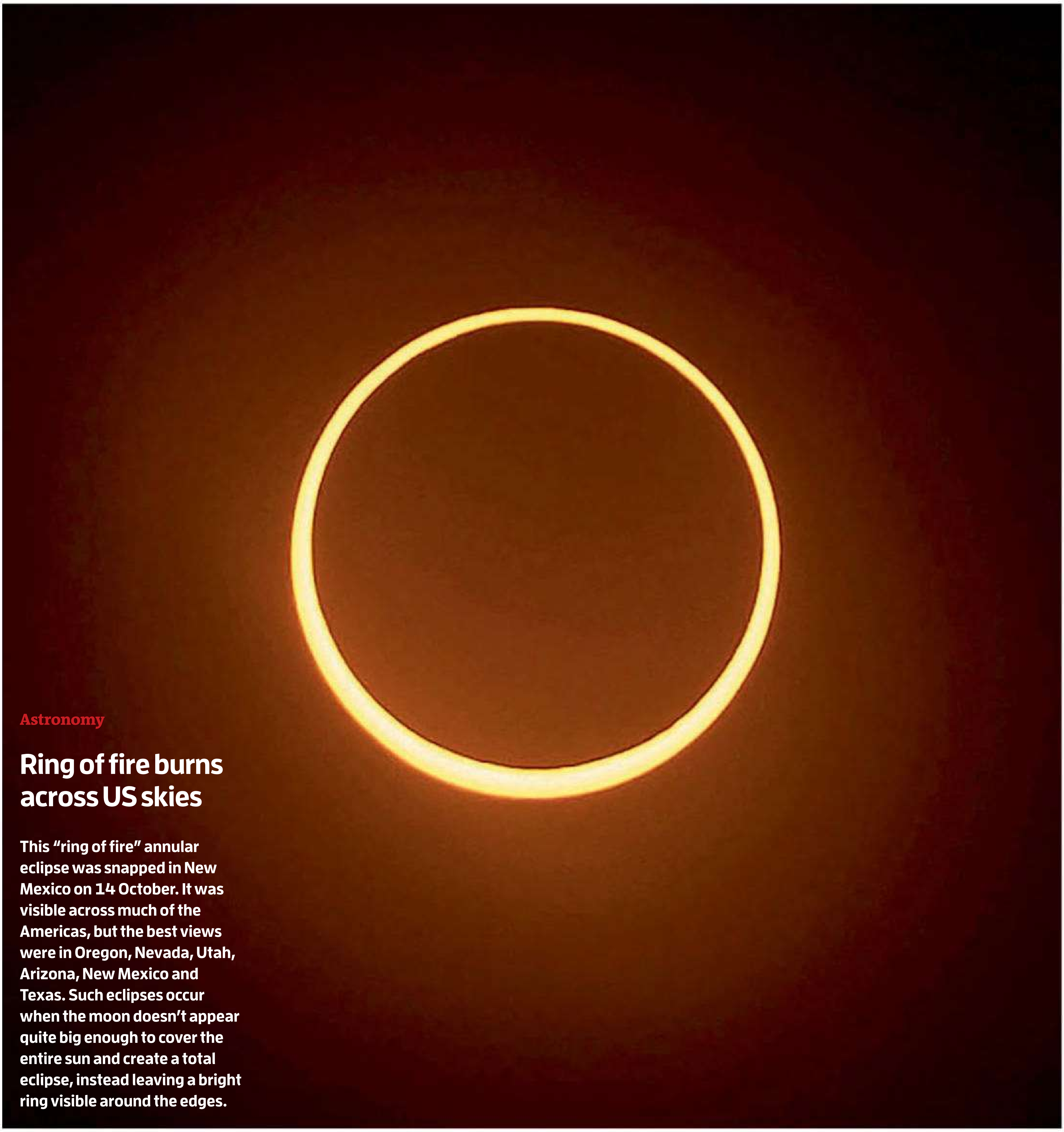


Astronomy

Ring of fire burns across US skies

This "ring of fire" annular eclipse was snapped in New Mexico on 14 October. It was visible across much of the Americas, but the best views were in Oregon, Nevada, Utah, Arizona, New Mexico and Texas. Such eclipses occur when the moon doesn't appear quite big enough to cover the entire sun and create a total eclipse, instead leaving a bright ring visible around the edges.

CHANCEY BUSH/ALBUQUERQUE JOURNAL VIA AP/ALAMY

Artificial intelligence

Drones killing without oversight?

Ukraine is using drones that can identify and attack targets without any human control. It is the first confirmed use of autonomous weapons on a battlefield, reports **David Hambling**

UKRAINIAN attack drones equipped with artificial intelligence are now finding and striking targets without human assistance, *New Scientist* has learned, in what is the first confirmed use of autonomous weapons or "killer robots". While the drones are designed to target vehicles such as tanks, rather than infantry, it is almost certain that the resulting explosions are killing Russian soldiers without a direct command from a human operator, although no casualties have been confirmed.

"A drone is likely to generate 'false positives', wrongly identifying an object as a target"

The drone is a quadcopter called the Saker Scout, which came into service in Ukraine last month and can carry 3 kilograms of bombs to a range of around 12 kilometres. Small drones operated by remote control have proved effective as bombers during the Russia-Ukraine war, dropping munitions made from modified anti-tank grenades. Larger drone-dropped munitions, as carried by the Saker Scout, will destroy even heavy tanks.

Saker is a Ukrainian company founded in 2021 with the goal of producing affordable AI for small businesses, in particular drone-based vision systems for applications including crop protection. When Russia invaded, the company switched to assisting the military. Its AI vision software can recognise 64 different types of "military object", including tanks, personnel carriers and other hardware, according to a spokesperson for the company.

Like other drones in use in Ukraine, the Saker Scout can be flown manually by a human operator. In this case, the AI points out targets and can spot and verify the nature of a target before striking it. It is integrated with Ukraine's Delta intelligence distribution system, which gathers data from drones, satellites and other sources to create a complete map of the battlefield.

The drone also has two autonomous modes. It can be sent into an area on its own to reconnoitre or it can be instructed to find and attack targets autonomously. The spokesperson told *New Scientist* that the Saker Scout had already been used in this latter mode on a small scale, confirming the use of autonomous weapons on the Ukrainian battlefield.

CELESTINO ARCE/NURPHOTO/SHUTTERSTOCK

A Ukrainian soldier inside a barn destroyed by Russian shelling

SAKER

The Saker Scout drone is able to attack targets autonomously

Using the drone in autonomous mode is less reliable than having a human in the loop, said the spokesperson, but they claimed the AI had proved effective and it was more important to deploy a weapon that worked now rather than waiting until it was perfect. Ultimately, Ukraine will need lots of drones that can operate autonomously, locating and striking targets at machine speed, the spokesperson said.

The potential use of autonomous weapons in Ukraine has been discussed for some time. Earlier this year, Mykhailo Fedorov, Ukraine's minister for digital transformation, stated that autonomous weapons were a "logical and inevitable" next step in drone development.

Paul Scharre at the Center for a New American Security, a think tank in Washington DC, says the basic technology is readily available. "Image classifiers have been around for at least 10 years and this type of software can be downloaded easily and trained on suitable data," he says. "But building a crude demonstration is one thing, the question is how much operational value such a system will have."

In particular, Scharre notes that an autonomous drone is likely to generate "false positives", wrongly identifying an object as a target. "The systems demonstrated so far have some degree of false positives, which is to be expected," he says. "Humans are naturally quite good at object recognition, so these AI tools are most likely to be used in situations where they are necessary – for example, where the communications link is jammed or where there's a risk the drone operator could be targeted."

No specific laws

The UN has been discussing legal restrictions on autonomous weapons or killer robots for many years and numerous campaign groups want to see them banned. A 2021 UN report claimed autonomous attack drones were used in Libya in 2020, but this was never proven. There are currently no specific laws covering autonomous weapons.

"A central feature of the debate has been the ability of such weapons to comply with the law of war and avoid civilian casualties," says Scharre. "If we see Ukraine beginning to deploy autonomous weapons in a way that is effective, avoids civilian casualties and hits military targets, it may be hard to object. But there is a very real risk that this could lead to indiscriminate use of such weapons later on." ▮

Environment

Vacuuming can reduce wildfire air pollution in homes

Chen Ly

CLEANING floors and surfaces is the most effective way to cut a major type of air pollution from wildfires that can persist inside buildings.

Smoke from wildfires contains pollutants including particulates, carbon monoxide and chemicals called volatile organic compounds (VOCs). Many of these VOCs can be dangerous to health. Formic acid, for example, can irritate the eyes and nose, while a compound called furan is a possible carcinogen.

To study the chemistry of wildfire smoke and how it interacts inside buildings, Delphine Farmer at Colorado State University and her colleagues injected smoke from burning pinewood chips into a test house 24 times over the course of two weeks.

They found that the VOCs tended to collect on surfaces, but once the smoke dissipated, they would be released into the air again. Some VOCs were buried quite deep into surfaces, which suggests they could take weeks or months to be re-emitted, says Farmer.

Testing ways to clean the house after smoke exposure, the team found that air-purifying measures, which included opening windows and running air filters, quickly reduced VOCs. However, after these measures were stopped, VOCs filled the air to earlier concentrations.

Surface-cleaning activities, such as dusting, vacuuming and mopping the floor with a commercial cleaner, were the most effective and long-lasting ways to lower VOCs in the air. Concentrations of the most common compounds, including formic acid, formaldehyde and furan, dropped by between 19 and 50 per cent after cleaning (*Science Advances*, doi.org/gsvp5c).

"I was surprised to see just how much better surface cleaning is," says Farmer. "But it's because you are addressing the problem at the source." ▮

Archaeology

Site used by ancient humans was also a latrine for giant hyenas

Soumya Sagar

ABOUT 1.4 million years ago, ancient humans in what is now Spain used to scavenge for food at a site that also served as a latrine for giant hyenas.

Fuente Nueva 3 in south-eastern Spain is one of the oldest archaeological sites in Europe associated with ancient hominins. As well as a large collection of primitive stone tools, excavations at the site have uncovered hundreds of examples of fossilised faeces, known as coprolites.

Paul Palmqvist at the University of Malaga in Spain and his colleagues analysed 216 of these coprolites with techniques including electron microscopy and X-ray diffraction. They also compared the coprolites with the faeces of modern-day spotted hyenas (*Crocuta crocuta*). Hyena clans often defecate repeatedly in particular places called latrines, possibly to mark their territory.

The results revealed that the coprolites came from giant, short-faced hyenas (*Pachycrocuta brevirostris*), which are now extinct. "The composition of the coprolites is identical to that of the hyena coprolites collected from a number of Pleistocene sites," says Palmqvist. "They also have the same geochemical, mineralogical signatures and the same presence of small pieces of bones as seen in extant hyenas." The presence of so many coprolites strongly suggests the giant hyenas used the site as a latrine.

> "We think that some of the carcasses came from animals that got trapped in quicksand"

Digs at the site have also yielded numerous stone tools and the bones of mammals, such as mammoths, horses, bison, weasels and water buffalo. Many bones have cut marks and signs of marrow extraction, hinting that they were butchered by humans.

Palmqvist and his colleagues think the hyenas and hominins both scavenged on leftovers of prey that had been killed by sabre-toothed cats and abandoned. It is likely that the hominins visited the site during the day, while the hyenas fed there at night (*Archaeological and Anthropological Sciences*, doi.org/kzrh).

However, there might be another reason why so many bones from megaherbivores, such as mammoths and hippos, are there: soil analysis indicates that the site may have been covered by quicksand.

"We think that some of the carcasses came from animals which got trapped in the quicksand," says Palmqvist. He points to the skeleton of a female mammoth with missing limbs, which was surrounded by stone tools, as well as 34 coprolites. This indicates that hyenas visited the carcass multiple times, and the hominins probably chopped off its legs to eat somewhere safer, he says.

However, the researchers can't rule out the possibility that hyenas were at the site some years after the humans feasted on the herbivores.

"I think the researchers have done a solid job of analysing the fossilised hyena poop and identifying *Pachycrocuta* as its source," says Briana Pobiner at the Smithsonian Institution in Washington DC. "Their use of surrounding evidence to conclude that it was a hyena latrine is remarkable."

Pobiner isn't entirely convinced that the upper layer behaved as quicksand that trapped mammoths, but the scenario is "intriguing", she says.

Palmqvist says his team is now analysing the sediments and working on estimating the weights of the megaherbivores to gather more evidence for the quicksand hypothesis. ▮

Spotted hyenas, like their ancient relatives, can be scavengers

ARCO/TUNS/IMAGEBROKER/ALAMY

Health

High-dose vitamin D could cut your risk of being hospitalised

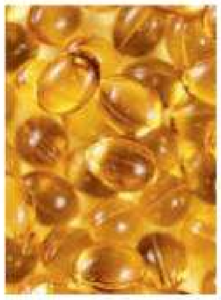
Carissa Wong

A HIGH daily dose of vitamin D may reduce your risk of being admitted to hospital. But this conclusion is based on a relatively small, short study.

Vitamin D is naturally made in the skin during exposure to sunlight and is found in some foods, such as egg yolks and oily fish. The compound is important for building healthy bones and helping the immune system ward off infections.

Health organisations such as the UK's national health services recommend that adults take 10 micrograms, or 400 international units (IU), of vitamin D every day, while the National Institutes of Health in the US advises that most adults take 600 IU, with both bodies cautioning against taking more than 4000 IU per day. Having too much vitamin D can cause a build-up of calcium in the blood, leading to symptoms such as nausea and kidney stones.

But Patrick LaRiccia at the University of Pennsylvania and his colleagues recently found that a daily dose of 5000 IU may reduce the risk of influenza-like symptoms. They wondered whether this higher-than-recommended dosage may also have other positive effects.



LYUBOMIR GIZDOV/ALAMY

Health bodies recommend adding low levels of vitamin D to your diet

So, the team asked 196 adults to take 5000 IU of vitamin D3, the form of the compound that animals make, every day for about nine months. The adults, aged 47 on average, were aware of the dose they were having. As vitamin D takes a while to build up in the blood, the team looked at data from two months after the first dose until the end of the study.

The researchers also analysed the data of more than 1900 people who weren't given the 5000 IU daily dose of vitamin D or any other pill, such as a placebo tablet. However, they were free to take vitamin D supplements if they wished. Given vitamin D's potential benefits, "it wouldn't be ethical to tell people not to take any supplement", says LaRiccia.

Towards the end of the study, about a fifth of the participants in this control group responded to a survey that asked about any vitamin D use, with 311 saying they had been taking a supplement. Across this group, the average reported dose was 1318 IU and the average age was 50.

Over 10 months, those on the 5000 IU dose had a lower risk of being hospitalised due to any cause, and had to visit the emergency room or be admitted to intensive care less than people in the other group (medRxiv, doi.org/kzrk).

However, LaRiccia says the team can't rule out the age difference as a possible cause of these results, with those in the high-dose group potentially avoiding hospital because they were on average three years younger.

The ethnicities of people in the two groups also differed, with fewer Hispanic and Latino people in the high-dose group, which may have affected the results, he says.

5000 IU

Daily dose of vitamin D taken by people during the study

The findings are promising, but the study was relatively small, says JoAnn Manson at Harvard University. It also didn't account for the placebo effect, she says, in which symptoms can improve if people take something they believe to be an effective therapy.

No participants reported side effects, but the study period was too short to monitor any long-term safety issues of such a high daily dose of vitamin D, says Manson.

Technology

Student uses AI to decipher word in ancient, closed scroll

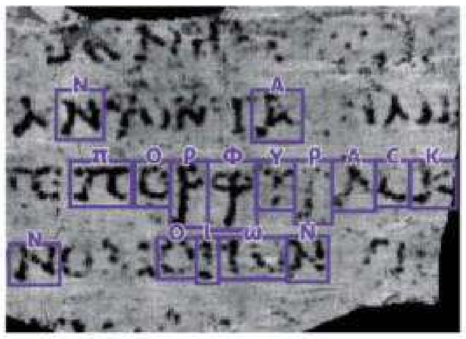
ALMOST 2000 years after they were buried by the volcanic eruption of Mount Vesuvius in AD 79, scrolls from a library in the ancient Roman town of Herculaneum have begun to reveal their secrets. The tightly wrapped papyrus scrolls were charred in the disaster, which also destroyed the nearby town of Pompeii.

By studying 3D X-ray scans of the scrolls, researchers have deciphered a word on one of them: πορφυρας (*porphyras*), meaning "purple". The breakthrough came from Luke Farritor, a computer science student at the University of Nebraska-Lincoln. His success involved training an artificial intelligence to identify nearly invisible ink-like patterns in the 3D scans.

"Seeing Luke's first word was a shock," says Michael McOsker at University College London. "It was immediately convincing, like 'Good lord, that's Greek.'"

Farritor analysed the 3D scans as a competitor in the open-source Vesuvius Challenge, which is awarding a series of prizes for deciphering the scrolls. He submitted his discovery in August.

At almost the same time, Youssef Nader, a data science graduate student at the Free University of Berlin in Germany, independently discovered the same word using a different AI technique to detect possible letter shapes. This provided an even clearer picture of the scroll segment, and is already yielding new, clear images of others. McOsker described Nader's first word snapshot as "even more impressive" than Farritor's.



VESUVIUS CHALLENGE

The Greek word for "purple" (third line) has been read in a scroll from Herculaneum

In the past, papyrologists could only study the Herculaneum scrolls by unrolling them, which damaged them, says McOsker. And even once people started using 3D imaging and computational techniques, "attempts to read the still rolled-up papyri were mirages", he says.

The breakthroughs may pave the way for someone to claim the Vesuvius Challenge's grand prize, worth $700,000, by reading four passages of text from inside two intact scrolls before 31 December.

Jeremy Hsu

Planetary science

Earth's core is oddly squishy and we may now know why

Karmela Padavic-Callaghan

THE inner core of our planet is surprisingly soft, and wiggling iron atoms may help explain why.

Jung-Fu Lin at the University of Texas at Austin and his colleagues wanted to understand why the hot, solid iron ball that sits at the centre of Earth is unexpectedly squishy, according to studies of seismic waves. So they fired a small projectile at 2-centimetre-diameter discs of iron, each disc being under 1.5 millimetres thick. On impact, the iron atoms experienced pressures up to 2.28 million atmospheres and reached temperatures of 4947°C for a few hundred nanoseconds. These conditions aren't as extreme as those found in the inner core, with a pressure of 3.6 million atmospheres and temperature of 5200°C, but they may be close enough to help us analyse its behaviour.

Lin and his colleagues used a laser to measure how fast sound waves move through the impacted metal and their measurements matched the findings from seismological studies of the inner core, indicating that its softness can probably be explained by assuming it is essentially a lump of pure iron (*PNAS*, doi.org/kzrj).

The researchers also used their measurements to run a computer simulation of the core's extreme conditions, modelling the behaviour of 30,000 iron atoms. This revealed that the atoms, which begin as a hexagonal crystal, wiggle from one spot in the structure to another, sort of like a game of musical chairs, says Lin. The researchers believe this collective motion causes the inner core's softness.

Similar studies may help us understand other planets, including "how their cores evolve, and how they generate and maintain their magnetic fields", says Hrvoje Tkalčić at the Australian National University. ▮

Analysis Nuclear arms race

Will countries resume nuclear bomb tests?

As global tensions rise, there are signs Russia, the US and China want to reawaken weapons programmes, says **Matthew Sparkes**

RUSSIAN DEFENSE MINISTRY PRESS O/UPI/SHUTTERSTOCK

A Russian intercontinental missile test, without a live warhead, in October 2022

NUCLEAR tensions have risen since the invasion of Ukraine, with Russia and other nuclear-armed powers reportedly updating disused weapon test sites in preparation for use once more. Now, Russian law-makers have voted to begin the process of rolling back a treaty banning such tests. Are we about to see a return of the most destructive weapons in the world?

The moratorium against nuclear testing rests on a patchwork of international accords. The Limited Test Ban Treaty was signed by the UK, US and Soviet Union in 1963, forbidding trials of these weapons in the atmosphere, underwater or in outer space, but permitting underground ones. Then, in 1996, the Comprehensive Nuclear-Test-Ban Treaty (CTBT) theoretically put a stop to underground testing too.

Yet the CTBT is unfinished. Despite 178 states having ratified it, the treaty won't officially come into force until action from eight more nations. China, Egypt, Iran, Israel and the US have signed, but not ratified, the agreement, and India, Pakistan and North Korea never signed it.

Despite this, nuclear test bans have proven effective. More than 2000 tests took place between the first US detonation, Trinity, in 1945, and the drafting of the CTBT. Since then, India and Pakistan each carried out a handful of tests in 1998, and North Korea is the only nation to have tested a nuclear weapon in the 21st century, with its last test taking place in 2017.

Russia's invasion of Ukraine and the subsequent ongoing war may have changed its view on testing, however. Russia ratified the CTBT in 2000, but on 17 October its lower parliamentary house, the Duma, passed a measure to revoke ratification. Duma speaker Vyacheslav Volodin said that the decision was being made because of the failure of the US to ratify the treaty and its "irresponsible attitude to global security issues".

"All three of the major nuclear powers seem to be preparing for tests"

Further readings and votes are needed to officially revoke the country's ratification of the treaty, and it is expected to remain a signatory, but this is another sign that the nation may restart testing that ended in 1990, with the Soviet Union's final detonation. In recent months, Russia has tested new nuclear delivery systems – without live warheads – and there have been prominent voices within the country calling for a resumption of nuclear tests.

In a recent speech, Russian president Vladimir Putin reportedly wouldn't be drawn on whether such tests were necessary, but he said: "As a rule, experts say, with a new weapon, you need to make sure that the special warhead will work without failures."

All three of the major nuclear powers seem to be preparing for tests. CNN reports that expansion and modernisation has taken place at China's test base in the Xinjiang region, at Russia's one in an Arctic Ocean archipelago and the US test site in the Nevada desert. Speaking to CNN, Jeffrey Lewis, who is at the Middlebury Institute of International Studies in California, said "there are really a lot of hints that we're seeing that suggest Russia, China and the United States might resume nuclear testing".

Even though nuclear weapons are back on the political agenda, there is no logical reason to test a bomb, says Andrew Futter at the University of Leicester, UK. This is because the need to test falls away as designs are proven and data is collected. "The technology has changed, but the basic science hasn't," he says. Most nuclear-armed states can run computer simulations to explore what will happen with new designs, he says.

"The trouble is that there's what logic would suggest will happen, and then there's reality," says Futter. ▮

Neurology

Brain mapped in most detail ever

A major research initiative has catalogued thousands of types of human brain cell and their locations, producing a resource that should help study neurological conditions, finds **Clare Wilson**

RESEARCHERS have drawn up the most detailed description ever created of the human brain, based on the thousands of different cell types that make it up.

The human brain cell atlas is a series of datasets about the various cell types within the brain and where they are located, defining this complex organ in more precise genetic and molecular detail than ever before.

The data comes from samples taken from deceased adults and children and from embryos and fetuses. The donors include some individuals who have certain medical conditions and others who don't.

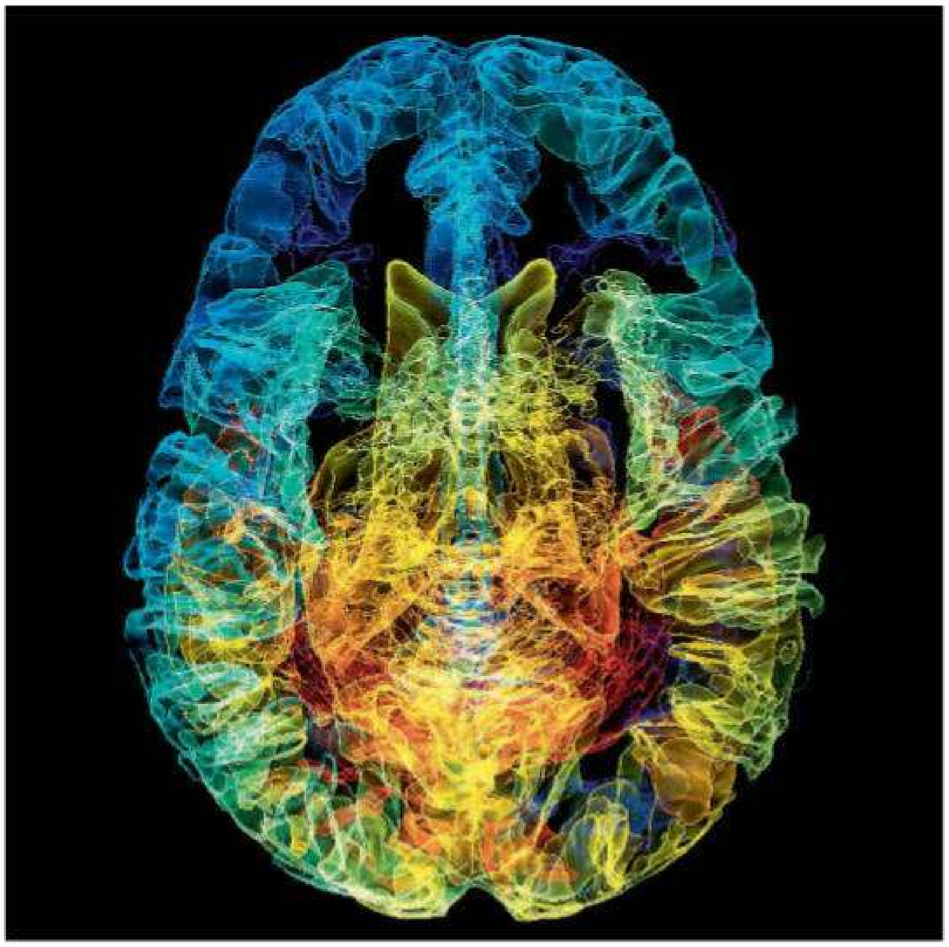
Samples from chimpanzees, gorillas and monkeys have also been included in order to shed light on brain evolution.

The resource has been compared to the enormous effort that went into the Human Genome Project, which led to multiple medical advances.

It is designed to lay the groundwork for further research into conditions that affect the brain, including neurological conditions such as Alzheimer's and Parkinson's disease, as well as mental health problems such as depression and schizophrenia. "If you're going to explore a new country, you need a map so you know where you're going," says Sten Linnarsson at the Karolinska Institute in Stockholm, Sweden.

Previous attempts to visualise the brain have involved scanning techniques such as magnetic resonance imaging (MRI). While brain scanning can be invaluable for making medical diagnoses of individuals – for instance, by revealing a brain tumour – it typically can't visualise anything smaller than about 1 millimetre.

The new atlas allows us to analyse the brain at a much smaller scale by identifying cell types taken from more than 100 different regions of the brain, depending on the species it comes from and its age.



K H FUNG/SCIENCE PHOTO LIBRARY

The human brain, shown in a coloured 3D magnetic resonance imaging scan

It was already known that there are many different types of brain cell, or neuron, partly based on the fact that they can look different or behave differently when grown in a dish. For instance, while most neurons send signals that trigger the next neuron down the line to fire, some send signals that stop the next neuron from firing.

But it was difficult to precisely identify the multitude of different neurons that exist until the advent of a technique called single-cell sequencing about 20 years ago.

This analyses the genetic material of a single cell to see which genes are turned on or off – in other words, which proteins it is making.

As single-cell sequencing techniques progressed, the US National Institutes of Health began funding two initiatives, which coalesced into a set of 24 papers published on 12 October.

The first initiative aimed to draw up a brain cell "census", consisting of a detailed description of all the different cell types in the human brain, based on which of their genes are active. The second sought to identify exactly where in the brain those types of neuron are found in order to produce a cell-based atlas of the brain – although, at the moment, it exists only as a huge set of databases, rather than a single visual representation.

The first draft involved efforts by multiple international research teams, sequencing millions of brain cells altogether.

3313
Number of different types of brain cell identified

105
Number of different anatomical locations looked at in the brain

Medical insights

Linnarsson was involved in several of the projects, including carrying out single-cell sequencing of 105 anatomical locations from four adult brains. The project identified 3313 different types of brain cell (*Science*, doi.org/gsvjpx).

Some insights into different medical conditions are already starting to emerge. "There are papers [due to come out] from geneticists that are mapping all the disease genes of brain diseases to our atlas," says Linnarsson. "There will be insights there for sure."

"There's an enormous incentive for understanding brain function, not just because it's such an intriguing question, but also because it can lead to therapies," says Arnold Kriegstein at the University of California, San Francisco, who is part of the team drawing up atlases for the fetal brain at different stages of development.

"In future, researchers may be able to use these tools to study cell-specific and circuit-specific activity which underlies complex cognition and behaviour," says Barbara Sahakian at the University of Cambridge, who wasn't involved in the research. "This will not only advance our knowledge of the healthy brain, but may also lead to novel treatments for brain disorders."

Mathematics

Artificial intelligence is helping us build a periodic table of shapes

Matthew Sparkes

MATHEMATICIANS attempting to build a "periodic table" of shapes have turned to artificial intelligence for help, hoping it will assist in finding yet-unknown shapes, but they don't know if it is 100 per cent reliable.

Tom Coates at Imperial College London and his colleagues are working to classify shapes known as Fano varieties, which are so simple that they can't be broken down into smaller components. Just as chemists arranged elements in the periodic table by their atomic weight and group to reveal new insights, the researchers hope that organising these "atomic" shapes by their various properties will help in understanding them.

The team has assigned each atomic shape a sequence of numbers derived from features such as the number of holes it has or the extent to which it twists around itself. This acts as a bar code to identify it.

Coates and his colleagues have now created an AI that can predict certain properties of these shapes from their bar code numbers alone, with an accuracy of 98 per cent – suggesting a relationship that some mathematicians thought might be real, but have found impossible to prove.

Unfortunately, there is a vast gulf between demonstrating that something is very often true and mathematically proving that it is always so. While the team suspects a one-to-one connection between each shape and its bar code, the mathematics community is "nowhere close" to proving this, says Coates.

"In pure mathematics, we don't regard anything as true unless we have an actual proof written down on a piece of paper, and no advances in our understanding of machine learning will get around this problem," says team member Alexander Kasprzyk at the University of Nottingham, UK.

Even without a proven link between the Fano varieties and bar codes, Kasprzyk says that the AI has let the team organise atomic shapes in a way that begins to mimic the periodic table, so that when you read from left to right, or up and down, there seem to be generalisable patterns in the geometry of the shapes (*Nature Communications*, doi.org/kzgq).

"In pure mathematics, we don't regard anything as true unless we have an actual proof written down"

"We had no idea that would be true, we had no idea how to begin doing it," says Kasprzyk.

The team hopes to refine the model to the point where missing spaces in its periodic table could point to the existence of unknown shapes, or where clustering of shapes could lead to logical categorisation, resulting in new ideas that could create a method of proof.

Graham Niblo at the University of Southampton, UK, says the work is akin to forming an accurate picture of a cello or a French horn just from the sound of a G note being played – but he stresses that humans will still need to tease understanding from the results provided by AI and create proofs of these ideas.

"AI has definitely got uncanny abilities. But in the same way that telescopes didn't put astronomers out of work, AI doesn't put mathematicians out of work," he says. "It just gives us a new tool that allows us to explore parts of the mathematical landscape that were out of reach." ▮

Conservation

Inventions based on threatened animals are on the rise

VOLODYMYR BURDIAK/ALAMY

The Asiatic black bear (*Ursus thibetanus*) is listed as a vulnerable species

THOUSANDS of patents have been filed for products derived from threatened wildlife such as bears, rhinos and pangolins, and commercial interest in these products appears to be growing.

These animals are among the species most threatened by illegal trade, with rhino horn, bear bile and pangolin scales in high demand for use in traditional Chinese medicine.

To investigate how businesses might exploit wildlife in the future, Amy Hinsley at the University of Oxford and her colleagues looked at wildlife-related patents on six threatened groups: bears, rhinoceros, caterpillar fungi, pangolins, horseshoe crabs and sturgeon. Using machine learning, they analysed all patents filed globally between 1970 and 2020 and found that 27,308 patents involved the selected groups.

Medicines were one of the most common types of product, alongside food and drink, such as an alcoholic beverage made with sturgeon caviar. "We also saw a patent for pangolin trousers – it was pretty wild," says team member Joss Wright, also at the University of Oxford.

In spite of trade bans, the number of patents involving most of the wildlife groups in the study has grown at a faster rate since 1988 than the number of patents involving other types of product. For example, 426 of the 526 patents for rhinoceros products in China were filed after the country's domestic trade ban in 1993 (Research Square, doi.org/kzq9). This hints that firms may be hoping for a relaxation of the regulations and could be developing products with that in mind.

The findings remind us that wildlife trade involves big business operations with their own research and development, says Zhengyang Wang at Harvard University. ▮

Chen Ly

Environment

Discarded toys produce more electronic waste than vapes

Chris Stokel-Walker

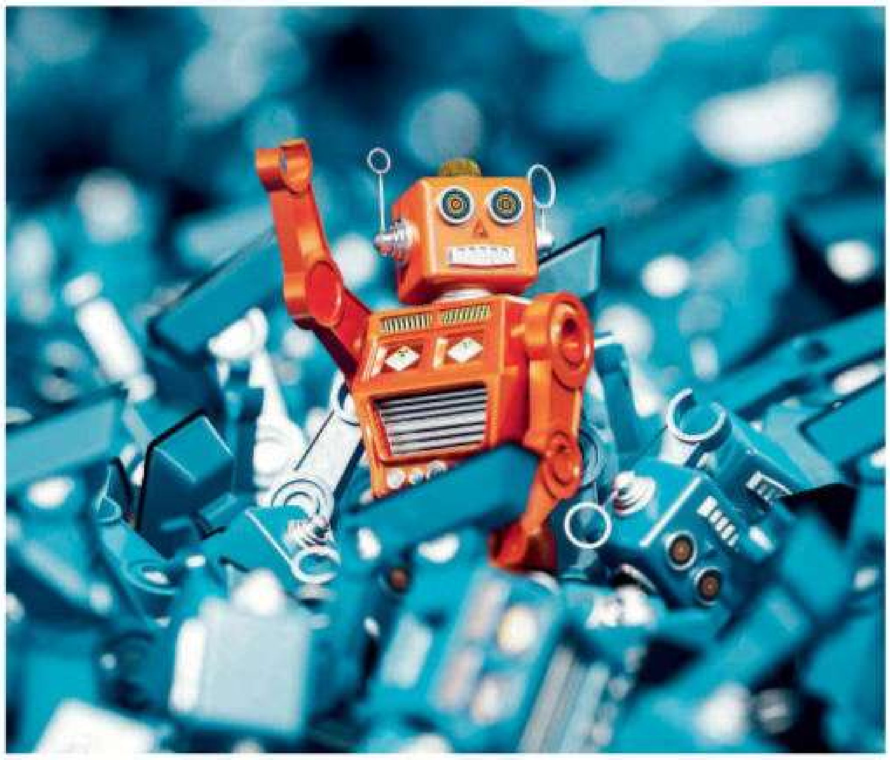
TOYS are a much larger contributor to electronic waste than vapes, according to an analysis by the United Nations.

To mark International E-Waste Day on 14 October, the Waste Electrical and Electronic Equipment (WEEE) Forum collaborated with the United Nations Institute for Training and Research to quantify how much electronic waste the world disposes of without realising it has the potential to be recycled.

In all, 9 billion kilograms of "invisible" e-waste is thrown away every year, worth nearly $10 billion, according to the analysis. Around one-third of this waste comes from children's toys containing hidden electronics, some 3.2 billion kilograms. Toys contribute 77 times more to the world's invisible e-waste than vapes, which account for 42 million kilograms each year. The UN estimates that 844 million vapes are thrown away every year.

"Electronic waste is our fastest growing waste stream," says Oliver Franklin-Wallis, the author of *Wasteland*, a book on waste disposal. "It's also by far our most valuable waste stream, when it comes to household waste."

However, very few people seem to realise that many common items they dispose of contain e-waste. Highlighting that was the purpose of the research, says Magdalena Charytanowicz at the WEEE Forum. "We're trying to make people understand that the items they may not suspect are electronics actually do contain a lot of precious materials, like copper and rare earth [elements]," she says.


DOUG ARMAND/GETTY IMAGES

Many children's toys contain electronic components

Globally, just 17 per cent of e-waste is collected and recycled, although the figure is far higher in some areas. Across the European Union, around 55 per cent of this waste is officially collected and reported.

People recognise that vapes are e-waste because of the very obvious battery that powers them, says Louise Grantham at REPIC, a UK-based WEEE compliance scheme. "Getting that association with toys I suspect is probably more difficult because it might be a big toy powered by a small battery," she says.

3.2 bn

Electronic waste coming from toys each year, in kilograms

That is supported by research from Switzerland, says Charytanowicz, which found that if the primary function of a device wasn't electronic, people using it didn't consider it to be electronic.

Franklin-Wallis says that overlooking the contribution toys make towards e-waste is a risk. "Anyone with small children knows just how much of this stuff is in every household now," he says, calling it a "tremendously rich source" for waste processors and the wider economy.

However, collecting that waste is easier said than done, particularly given the current state of recycling infrastructure in countries such as the UK, according to Franklin-Wallis. "The collection of electronic waste is relatively poor," he says. "I think there's still a job yet to be done in informing the public on the value of the materials, how to dispose of them and recycle them safely."

One way to tackle that, says Charytanowicz, would be to implement a UN treaty that regulates the recycling of e-waste at a global level – similar to one that binds countries to recycling plastics. ■

Space

Asteroid Bennu contains key ingredients of life

Karmela Padavic-Callaghan

WE HAVE had a first look at samples from a 4.5-billion-year-old asteroid and they are full of carbon and water – the necessary ingredients for life as we know it.

The samples were scraped from asteroid Bennu by NASA's OSIRIS-REx spacecraft in 2020. Its sample-filled capsule touched down in the Utah desert on 24 September. The capsule was then transported to NASA's Johnson Space Center in Houston, Texas, where analysis began on its contents.

So far, the researchers have studied just the charcoal-coloured dust and tiny Bennu pebbles that settled on the lid and around the base of the sample-holding canister. They subjected this material to a battery of analytical tests, which revealed the presence of water, carbon and several organic molecules.

"The bounty of carbon-rich material and the abundant presence of water-bearing clay minerals are just the tip of the cosmic iceberg," said Dante Lauretta at the University of Arizona, the principal investigator on the OSIRIS-REx mission, in a statement.

"Carbon and water are not life, but they are the building blocks that life needs, and there are other pivotal materials and minerals there," says Timothy Glotch at Stony Brook University in New York. He says analysing the samples further will show how water may have changed the rocky asteroid over time, beginning early in the development of the solar system.

Paul Byrne at Washington University in St. Louis, Missouri, says that this may have implications for how water came to Earth and the timeline of water's presence on other planets. Learning just how much water there is on Bennu could tell us "whether Earth was born wet, or born dry and then water was brought to it", he says. ■

Palaeontology

Early humans lived at high altitude as much as 2 million years ago

Michael Marshall

ANCIENT humans were living in the highlands of what is now Ethiopia as early as 2 million years ago. A reanalysis of a fossilised jawbone from the region confirms that it belonged to a *Homo erectus*, and represents the earliest evidence of hominins living in such high-altitude areas.

The highlands are "a third pole for human evolution in Africa", says Margherita Mussi at the Italo-Spanish Archaeological Mission at Melka Kunture and Balchit, based in Rome.

Mussi and her colleagues re-examined the lower jawbone of an infant, which was discovered in 1981 at a site called Garba IV in the Ethiopian highlands. Garba IV is one of a cluster of sites known collectively as Melka Kunture. Mussi has nicknamed the jawbone "Little Garba".

The jawbone had already been identified as that of an early member of the genus *Homo*, which includes our own species, *Homo sapiens*, and several now-extinct groups. However, it wasn't possible to confidently identify the species.

Mussi and her team used synchrotron imaging on Little Garba's teeth, which hadn't yet erupted from the jawbone. They compared the shape of the teeth to those of multiple hominin species. "The teeth are a very good marker, so we can say for sure this is indeed an early *Homo erectus*," says Mussi.

In a 2021 study, Mussi's team re-dated the Garba IV site. It consists of layers of sediment laid down over time. In them, the researchers found traces of past shifts in Earth's magnetic field, which could be matched to records elsewhere. Based on this, they now conclude that Little Garba is 2 million years old, making it one of the oldest *H. erectus* ever found.

The jawbone of a *Homo erectus* child found in Ethiopia

ITALO-SPANISH ARCHAEOLOGICAL MISSION WITH ARCCH PERMIT

It may even be that the species evolved in the highlands. "We don't know if *Homo erectus* evolved at lower altitudes and came up, or if it evolved locally," says Mussi.

The researchers also re-examined stone tools found in the sediments at Garba IV. They say there is a transition from older and simpler Oldowan tools to more sophisticated Acheulean tools between 2 million and 1.95 million years ago. The Acheulean tools were harder to make because they required planning, but they opened up a wider range of foods.

Mussi argues that the *H. erectus* population had to adapt to the highlands and developed new styles of stone tools to do so (*Science*, doi.org/kzf7).

The identification of Little Garba as *H. erectus* looks solid, says Clément Zanolli at the University of Bordeaux in France. He is less convinced by the transition from Oldowan to Acheulean, because there aren't many Oldowan tools in the older layers. For Zanolli, "the most exciting aspect" of the study is the location. "It's the oldest [hominin] we know to have reached the high plateau of Ethiopia," he says.

Garba IV is about 2000 metres above sea level, which isn't so high that low oxygen levels are a major challenge, says Zanolli. It would have been colder than lowland areas, but may have been more hospitable. "In this high-altitude environment, you have more trees, more bushes, probably more animals," he says. "So it's very likely easier to find food and to survive." ▮

Environment

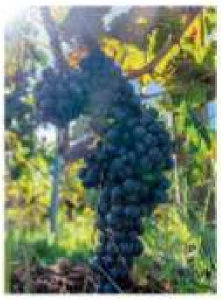
Climate change may be improving Bordeaux wines

WINES from the Bordeaux region of France tend to be better when the grapes are grown in years with wet winters and hot, dry summers. Climate change is making these weather patterns more common, which may partly explain why Bordeaux wines have been improving over the past 70 years.

Andrew Wood at the University of Oxford and his colleagues have analysed records of temperature, rainfall and critics' ratings of Bordeaux wines, which are mostly reds, from 1950 to 2020. They focused on Bordeaux because its vineyards are exclusively irrigated by rain, and wine critics provide annual ratings of the region's wines.

In general, the highest-rated wines tended to be produced in years with wet winters, when vines are dormant, and hot, dry summers, when grapes ripen (*iScience*, doi.org/kzbd).

High rainfall in winter may produce better grapes because, if "the plant's water reserves are filled up in winter, it can draw on that in spring and grow more vigorously", says Wood. And drier conditions in summer may be more favourable because they help concentrate sugars and aromatic compounds in the ripening grapes, says Wood.



IRINA NAOUMOVA/ALAMY

Grapes ready for harvest in the Saint-Emilion part of the Bordeaux wine region

The researchers found that critics' ratings of Bordeaux wines have generally risen since 1950. This may be thanks to improvements in wine-making and efforts to match consumer preferences, but it may also be because climate change has made wet winters and hot, dry summers more frequent in France, says Wood. He says vineyards around the world that grow the same grape varietals, such as Cabernet Sauvignon, may also benefit from the weather changes. ▮

Alice Klein

Space

Two giant planets collided and vaporised in a distant star system

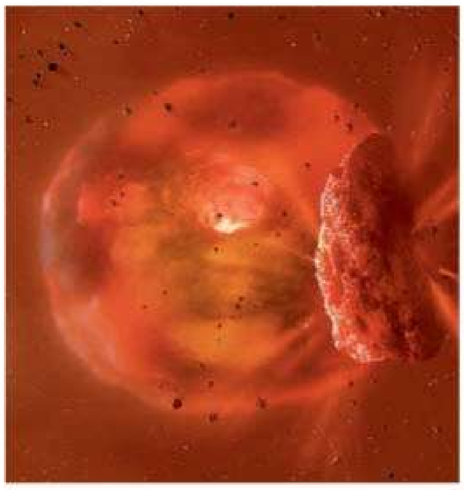
Jonathan O’Callaghan

A STAR system 1800 light years from our own may have been the scene of a cataclysmic collision, as two giant planets crashed together and were incinerated, leaving behind a glowing-hot doughnut. If so, it is the first time we have seen a planetary collision, and its aftermath, as it happened.

In 2021, astronomers spotted a strange event in which a sun-like star, dubbed ASASSN-21qj, dimmed by as much as 95 per cent. When Matthew Kenworthy at Leiden University in the Netherlands and his colleagues looked at past observations of the star, they found it had doubled in brightness three years before the dimming.

The cause of that brightening and then dimming, they think, was two giant planets crashing together, with a resultant doughnut-shaped disc of heated dust and gas orbiting in place of the planets and obscuring our view of the star years later.

“We went through a whole series of possible ideas,” says Kenworthy. “The one that seems to fit all the data we have is a collision of two ice giants. It’s the first time this has been seen.”


MARK GARLICK

An illustration of the huge, glowing doughnut produced by planets colliding

The two planets would each have been perhaps dozens of times Earth’s mass, comparable to Neptune, and they would have orbited the star at a distance similar to that of Jupiter around our sun. As they smashed together, they would have been “pulverised, totally reduced to molten muck”, says Kenworthy, leaving behind a “giant ball of silica vapour” about seven times as wide as our sun.

Up close, an observer would have seen a “bright red glowing collision”, says Kenworthy, with rock and debris being blasted out from the planets’ solid cores.

A white-hot remnant would have burned at the centre of this ball, eventually forming into a torus-shaped ring orbiting the star, with a scorching temperature of some 700°C.

That is about half as hot as what would have been expected if the two planets were rocky, leading the researchers to surmise that the worlds were rich in water vapour, making them ice giant planets like Neptune and Uranus. The remains may eventually condense into a new planet in a few thousand years (*Nature*, doi.org/kx92).

How the event happened is unclear. The two planets may have been perturbed in their orbits by a passing star or another planet before colliding, releasing the equivalent energy in an instant as a small star burning for two years.

“We have good evidence that planetary collisions do occur,” says Jonathan Marshall at the Academia Sinica Institute of Astronomy and Astrophysics in Taiwan. For example, the moon is thought to have been created when a Mars-sized object called Theia smashed into Earth.

Marshall, however, has previously proposed that the dimming of ASASSN-21qj was due to comets breaking apart in the system, not a planetary collision. “We didn’t feel there was enough mass to justify more than small bodies involved,” he says.

André Izidoro at Rice University in Houston, Texas, says “super-Earths and mini-Neptunes are super common close to other stars, so giant impacts among them should also be super common”.

However, such events should become less frequent as a star system ages. In our solar system, it is thought that this tumultuous period ended about 100 million years after the birth of the sun, but Kenworthy and his colleagues believe ASASSN-21qj is 300 million years old. If this is correct, it would show that giant impacts can happen later, says Izidoro. ▮

Health

Blood test tweak could make intensive care treatment safer

USING smaller vials to collect blood samples from people in intensive care could help prevent risky transfusions and preserve valuable supplies of donated blood.

Most hospitals around the world use standard blood collection tubes, which withdraw 4 to 6 millilitres of blood, when carrying out tests on people in intensive care units (ICUs). But most of these tests – which check organ function, clotting and respiratory health – require less than 0.5 ml of blood.

With multiple blood samples often being taken from people in ICUs every day, this can lead to substantial blood loss and anaemia.

“After eight days in intensive care, the amount of blood loss is equivalent to donating a unit of whole blood [around 350 to 525 ml],” says Deborah Siegal at the University of Ottawa in Canada.

Roughly 40 per cent of people in intensive care need blood transfusions, which carry the risk of allergic reactions and infections. Taking unnecessarily large blood samples adds to that need, says Siegal.

Now, she and her colleagues have studied more than 27,400 adults who had been in intensive care for at least two days at 25 ICUs across Canada. For the first six weeks of the study, all of the ICUs used standard test tubes to collect blood samples. Every six weeks thereafter, two of the ICUs switched to using vials that collected between 1.8 and 3.5 ml of blood.

“After eight days, the amount of blood lost to blood tests is equivalent to donating a unit of blood”

By analysing the number of transfusions given, the team found that using smaller vials resulted in one fewer transfusion per 10 people in intensive care than using the standard tubes (JAMA, doi.org/kzbr).

This amounted to saving about 1500 units of blood over an almost two-year period, says Siegal. The smaller tubes didn’t affect the quality of the blood tests carried out, she says, and transitioning to smaller tubes also seemed to reduce the risk of anaemia. ▮

Carissa Wong

Archaeology

Viking queen was a powerful figure

A MYSTERIOUS queen named Thyra who lived during the Viking era may have been one of the founders of what is now Denmark.

Denmark's Viking Age lasted from around AD 800 to 1050. A key figure was Harald "Bluetooth", who was king from about 958 until his death in 987. Harald's parents were Gorm, who came to power in around 936, and Thyra.

Under these two generations, Denmark became a unified state. But the lack of written records means we know little more. Now, Lisbeth Imer at the National Museum of Denmark and her colleagues have found the name Thyra on four runestones – slabs of engraved granite – from the mid-900s (*Antiquity*, doi.org/kzgc). This hints Thyra must have been very powerful in her own right, says Imer. **Michael Marshall**

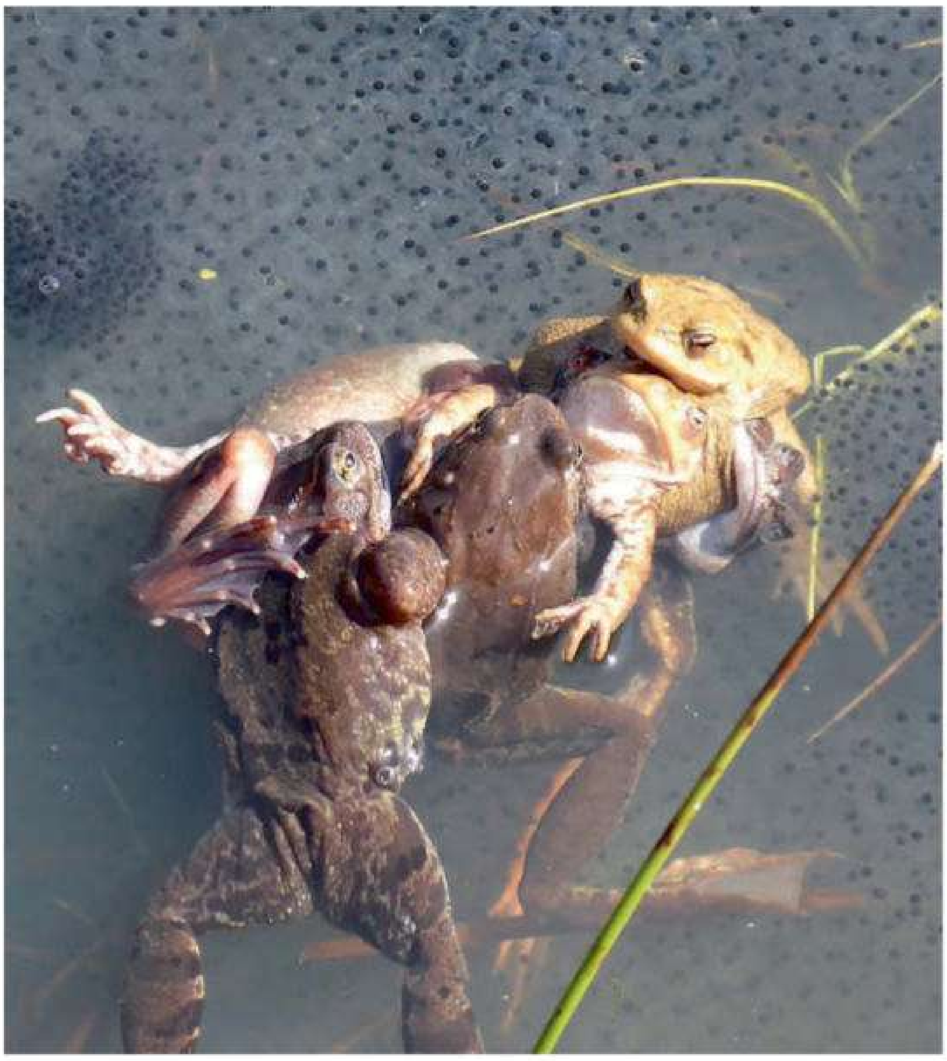
Space

Melt dust to make roads on the moon

LUNAR dust could be melted into paving slabs to create roads on the moon, enabling easier transport across its surface.

Miranda Fateri at Aalen University in Germany and her colleagues used a 12-kilowatt laser to heat a powder made of plagioclase, olivine and pyroxene, developed as a substitute for lunar dust. At a temperature of 1200°C, the dust compacted and turned into a black, glassy structure with a compression strength that is comparable with that of concrete. It could be usable as a road surface (*Scientific Reports*, doi.org/kzf9). "It makes transport on the moon easier," says Fateri.

Deploying a laser on the moon might be hard, but the researchers calculate that a 1.5-metre-wide lens could instead be used to focus sunlight and produce the same effect. **Jonathan O'Callaghan**


COURTESY OF CAROLIN DITTRICH

Zoology

Female frogs sometimes play dead to avoid mating

MALE frogs often coerce female frogs into mating, but some females have ways to avoid harassment, including playing dead.

With the European common frog (*Rana temporaria*), males often vie for females, sometimes leading to deadly clashes as individuals are submerged under a competing group of males.

"It could be that there are several males clinging to one female, which often leads to the death of the female," says Carolin Dittrich at the Natural History Museum in Berlin, Germany.

To investigate if female frogs have ways to avoid this attention, Dittrich and her colleagues collected common frogs – 96 females and 48 males – during the breeding season. They repeatedly placed one male and two differently sized females in a box filled with 5 centimetres of water. The frogs were then allowed to move freely for 1 hour while the team recorded their behaviour.

Of the 54 female frogs that were embraced by a male as part of the mating process, 83 per cent rotated away, making it the most common escape tactic. Many used more than one technique. Another popular avoidance measure – observed in 48 per cent of females – was to make what is known as a release call, which is generally how males signal to other males that they are male so should be left alone. Thirty-three per cent of clasped females exhibited "tonic immobility", otherwise known as playing dead. In 46 per cent of the cases, females evaded the male's attention (*Royal Society Open Science*, doi.org/kzf8).

The work shows that the female frogs aren't as passive as people often think, says Dittrich. **Chen Ly**

Really brief

ALAN O'NEILL

Massive wind farm powers up

The first turbine at Dogger Bank Wind Farm has begun sending power to the UK grid. The plan is to have 277 turbines, making it the world's largest offshore wind farm. The Voltaire jack-up vessel (pictured) – taller than the Eiffel Tower when it plants its four legs on the seabed – is installing the towering structures.

The Neanderthals hunted cave lions

Neanderthals sometimes hunted now-extinct big cats called cave lions (*Panthera spelaea*). A cave lion skeleton showing signs of hunting and the remains of a pelt are some of the earliest evidence of ancient humans killing top predators as opposed to plant-eaters (*Scientific Reports*, doi.org/gsvjpd).

Transistor could let watches use AI

A transistor made of molybdenum disulphide and carbon nanotubes can run artificial intelligence processes using 100 times less electricity than the standard transistors in silicon-based chips. It could help spur the development of a new generation of smartwatches (*Nature Electronics*, doi.org/kzgj).

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Cocoon is reminiscent of H. R. Giger, says **Jacob Aron** p28

Comment

Reinventing education

Instead of panicking about students using ChatGPT to cheat, we should be using AI to rethink how we learn, argues **Okezue Bell**

SIMONE ROTELLA

ON A Monday afternoon in May, a final-year student, fresh off the Texas A&M University-Commerce graduation stage, received a shocking email. "The final grade for the course is due today at 5 p.m.," it read. "I will be giving everyone in this course an... incomplete."

According to a report in the *Washington Post*, agricultural sciences professor Jared Mumm had run his students' essays through the AI tool ChatGPT, which had detected its own use in the work – an offence that warranted a zero on the assignment. But in reality, it was ChatGPT that was the plagiariser, incorrectly claiming credit for several student-written papers.

Mumm's concerns had some merit, though. Many students are using ChatGPT to write essays or to cheat on tests. Some teachers are worried that academia may be crumbling under the pressure of 170 trillion text data parameters packed into a tempting AI chatbot.

The education sector is trying to get a handle on this technological maelstrom. Educational institutions have banned OpenAI's website. Governments are building classroom frameworks for AI use. Plagiarism detectors GPTZero and TurnItIn attempt to detect AI-facilitated writing, but they are still in need of improvements. Meanwhile, AI companies are drowning teachers and government regulators in new and more accessible chatbots.

However, I believe the main problem with the response to such generative AI in education is that the focus is on regulation, not reformation. We should instead be asking: why is it so easy to use these systems to cheat? And why aren't we using them to learn?

Traditional learning is extremely linear: memorise content, receive assignments, take a test, rinse and repeat. Students are constantly absorbing rote methods of executing a task or calculation, as opposed to discovering answers by conceptualising the work. As a result, the right answer takes priority over the right thinking, and AI chatbots can get to that right answer very conveniently.

Recognising this, in 2021, I founded Fidutam, a civil society group mobilising citizen, private and public sector stakeholders for responsible technology. As a youth-led organisation that now has more than 1500 members, one of our main focuses is technology in education. We built an application that uses GPT-4 to generate courses on any topic a student or teacher chooses. The model acts like a more streamlined version of a standard Google search, ensuring that students are presented with factual information and reducing the effect of AIs "hallucinating" and producing incorrect information.

To supplement the app, our team also designed an assessment system for teachers centred around class discussions and students' verbal explanations of content, using ChatGPT and our app as an educational aide. We now have just over 2000 young people and teachers across the US, sub-Saharan Africa and South Asia plugged into our platform. Girls in Ethiopia have used it to understand menstrual health, while neurodiverse teens from low-income New York households used it as an English comprehension tutor. After four months, we had some students jumping one or two grade levels in core subjects when benchmarked via national exams. Perhaps most impressively, they were doing this with limited access to textbooks or teachers with specialised degrees.

So the discussion about how to integrate AI and education isn't just for big tech and policy-makers, it is one for us all. Because if we build and use AI effectively, we can create an education system where students are assessed on the quality and depth of their knowledge, not the content of an exam. This won't be the pathway to an easy A, but to an accessible and more effective education. ▮

Okezue Bell is an AI activist, research student and founder of Fidutam, a civil society group

No planet B

Something smells fishy I knew there were problems with sea-farmed salmon, but after seeing the damage inflicted by life in an ocean pen, I will never buy it again, says **Graham Lawton**

Graham Lawton is a staff writer at *New Scientist* and author of *Mustn't Grumble: The surprising science of everyday ailments*. You can follow him @grahamlawton

WE PICKED the wrong day to take a small boat across a fjord in wild western Iceland. The weather was challenging, to say the least, with a heavy swell and lashing rain. We were trying to get out to a salmon farm to see it for ourselves, but were beaten back.

I was in the country on a press trip organised and funded by the outdoor clothing company Patagonia, which campaigns on numerous environmental issues. In this case, it was highlighting the harms of open-net salmon farms, where fish are confined in circular pens in the sea. Iceland is quite new to this, but it is big business in Norway, Scotland, the Faroe Islands and Canada. I knew there were problems associated with it, but continued to eat its bounty from time to time. Never again.

"It's a monstrous way to produce food," says Jón Kaldal at the Icelandic Wildlife Fund. The salmon are confined in nets 35 metres in diameter and up to 18 metres deep. Each holds up to 120,000 fish in densities much greater than in the wild. They are kept there for 16 to 24 months until they are large enough to be slaughtered. Then they are sucked out of the pens in a giant salmon hoover and dispatched with a blow to the head or electrocuted.

Their time in the pens is an ordeal. They chafe against the net and fight with one another, injuring their fins and tails. They are eaten alive by salmon lice, small crustaceans that burrow into their skin. A wild salmon might have one or two lice, but many farmed ones are riddled with them. The lice thrive in an environment packed with salmon that can't swim into fresh water to force the pests to drop off. "It's a paradise for lice," says Simen Sætre, co-author of *The New Fish*, the product of a five-year investigation into the Norwegian salmon industry.

Some fish are so badly affected by lice that large patches of skin get eaten away entirely, says Elvar Friðriksson at conservation group the North Atlantic Salmon Fund. Around 20 per cent of salmon die from louse injuries or stress, says Kaldal. Outbreaks of a virus called infectious salmon anaemia pose yet another burden. "The welfare issue is absolutely horrendous in this business," he says.

I saw for myself the damage inflicted by a life in a sea pen, in the shape of a farmed salmon that had escaped along with thousands of others and was recaptured and killed in a river. Its fins were ragged and its tail stunted, while one of its eyes had been eaten away almost to the bone. Even in this lousy and bedraggled state, a fish will end up on the plates of consumers.

> **"Some sea-farmed salmon are so badly affected by lice that large patches of their skin get eaten away entirely"**

There are issues beyond animal welfare. The fish produce tonnes of faeces, which simply fall onto the seabed along with uneaten food pellets, causing dead zones under the pens. The pesticides used to de-louse the fish also kill other crustaceans. The nets are often coated with copper oxide to stop them fouling up with marine organisms, but this leaches into the water. The farms also produce large quantities of microplastic pollution from degradation of the nets and feeding tubes, which are scoured by pellets that are shot into the pens at high speed "like a sandblaster", says Kaldal.

The fish are fed other fish that are perfectly fit for human consumption, often caught in developing countries, depriving people who need it of high-quality protein and converting it, inefficiently, into a premium product for Western consumers. And of course the fish periodically escape and interbreed with wild salmon, diluting their gene pool.

"This is factory farming," says Kaldal. "It's not sustainable." And yet when I used to buy salmon in my supermarket, it was labelled as "responsibly farmed".

It is possible to farm salmon without trashing the environment and torturing the fish. Land-based tanks contain the waste and can be kept louse-free. Iceland has a growing number of these. "What you need is land, cheap electricity and water, and that's pretty much all we have," says Friðriksson – but the costs are higher and the welfare issues not entirely resolved. Fish farmed this way are on sale in Iceland, but not really in the UK.

To be fair to the open-pen industry, in Iceland at least, it follows rules laid down by the government, which are based on advice from marine scientists. Icelandic salmon farming company Arctic Fish – which had initially agreed to take us out to the pens, but backed out at the last minute – put up a spokesman, Daníel Jakobsson. He accepts there are problems in the industry, but insists the company is complying with its environmental and welfare obligations. The death rate in the pens is actually only 5 per cent, he says.

Nonetheless, I will be voting with my shopping trolley. Sea-farmed salmon is off my list. "The environmental argument should be enough for people not to eat this," says Friðriksson. "Why would you want to eat this?" ▮

Graham's week

What I'm reading

How Religion Evolved: And why it endures *by Robin Dunbar.*

What I'm watching

The Long Shadow *on ITV1, a dramatisation of the victims of serial killer Peter Sutcliffe.*

What I'm working on

An exciting but possibly hairy trip to the Democratic Republic of the Congo.

This column appears monthly. Up next week: Annalee Newitz

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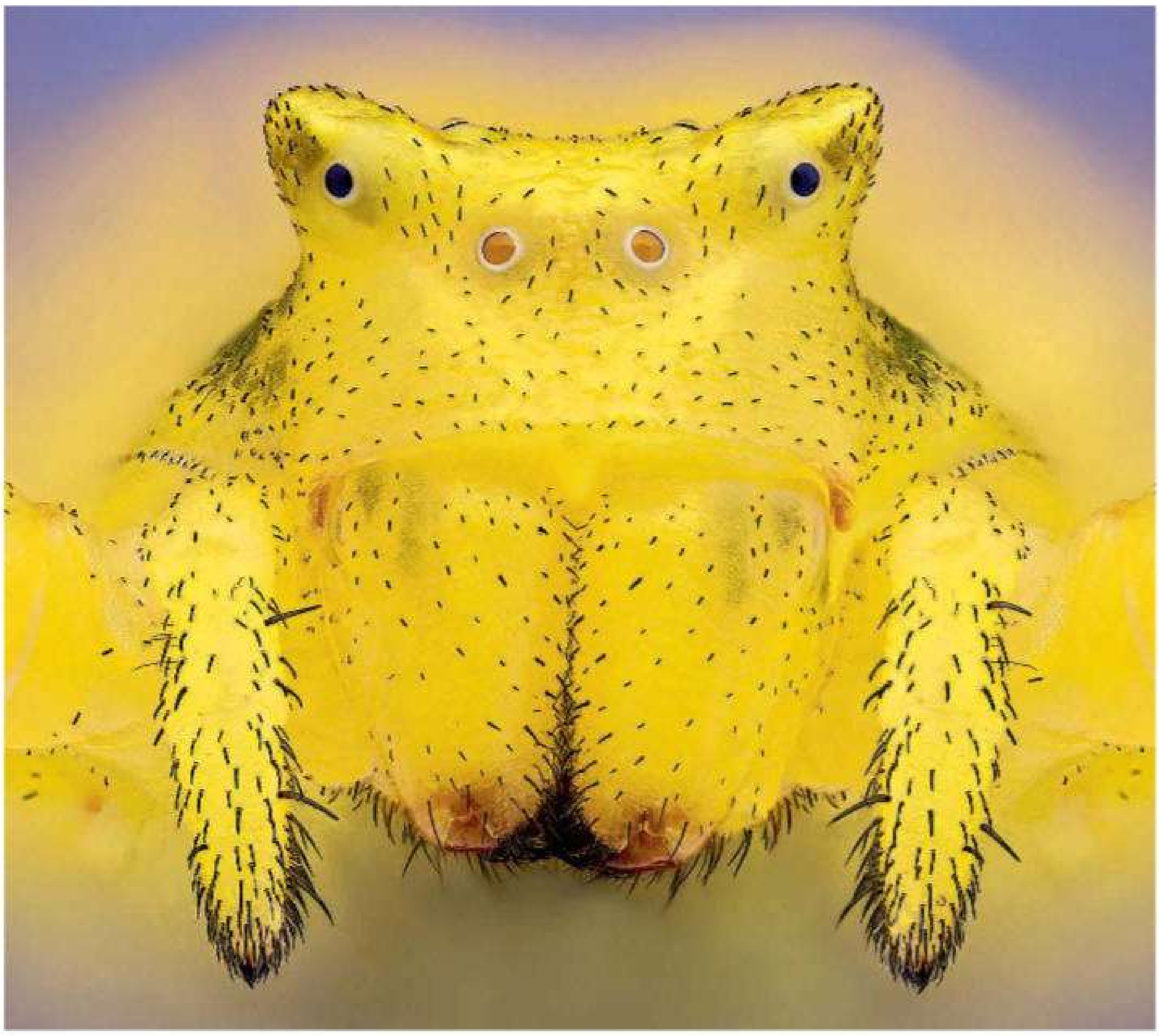

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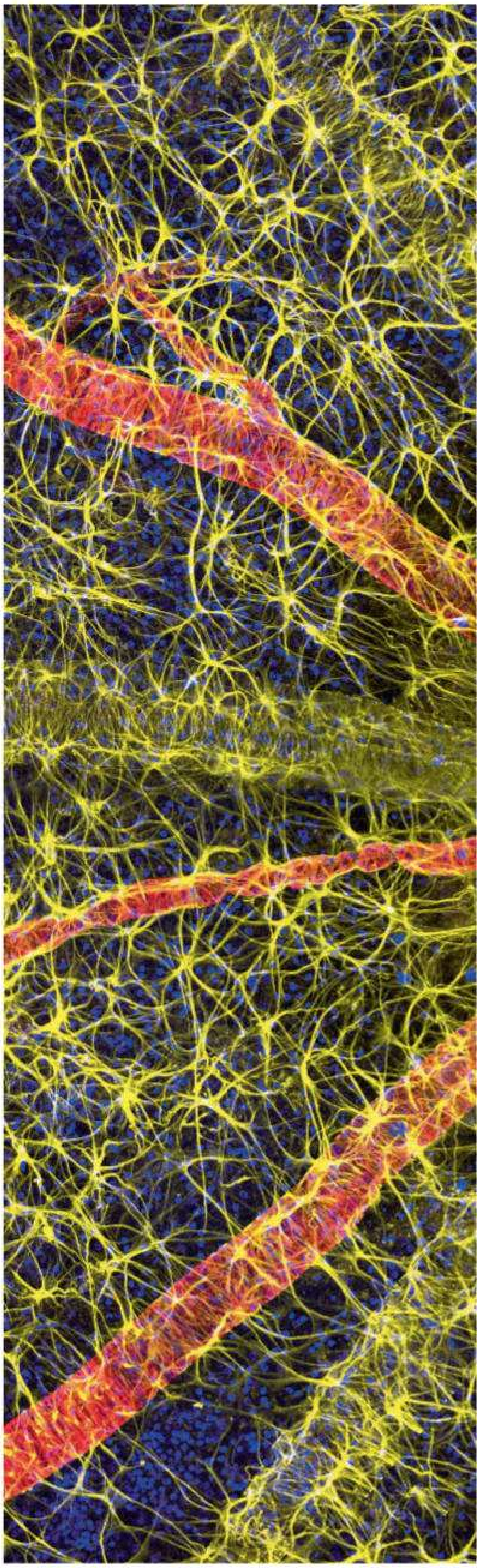
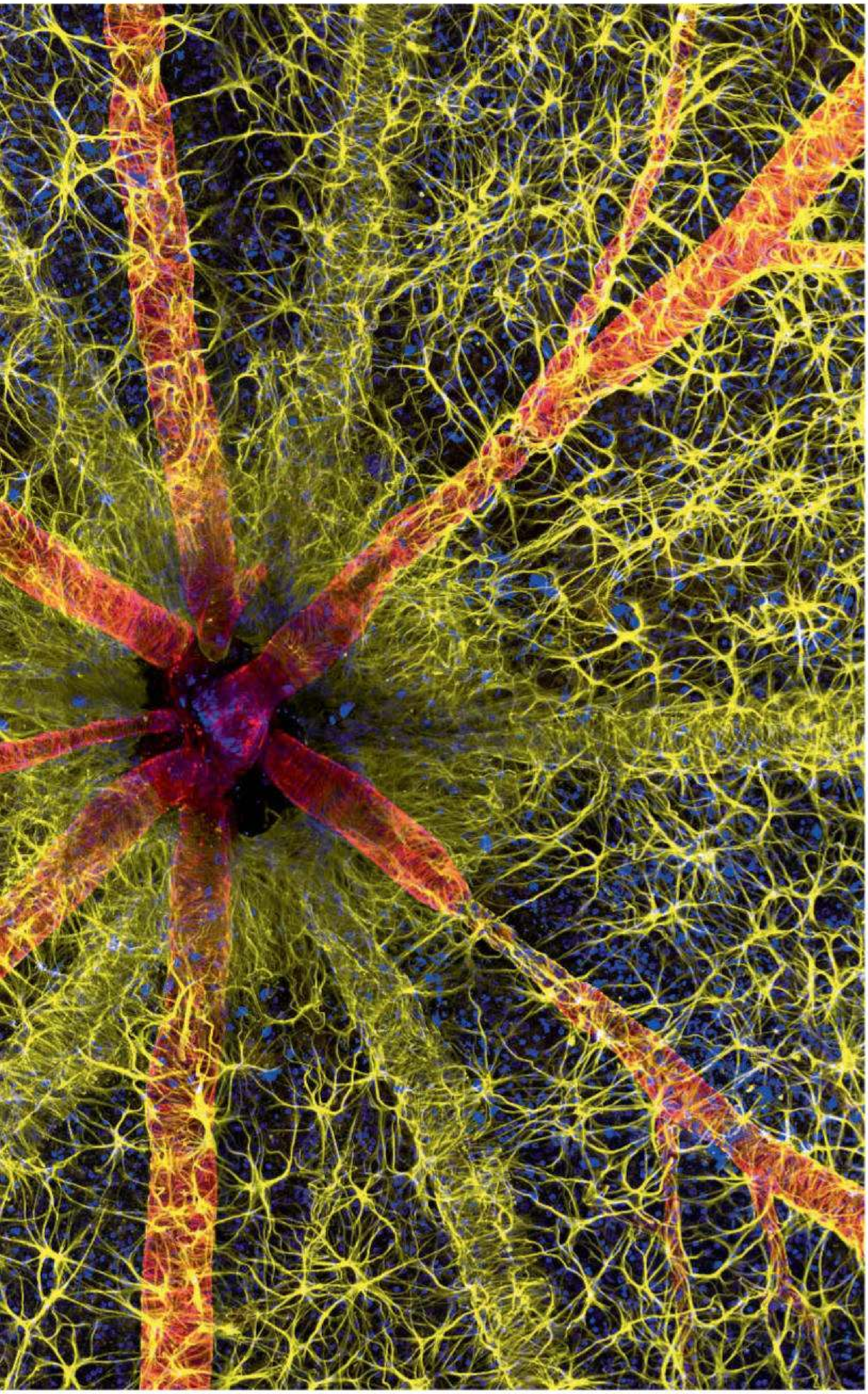


HASSANAIN QAMBARI & JAYDEN DICKSON



Magnifycent

Nikon Small World

THIS dazzling compilation of life under the microscope showcases some of the best photos entered into 2023's Nikon Small World Photomicrography Competition.

Scooping the top prize is a picture of a rat's optic nerve head (main image), which is where all the retinal nerve fibres that travel to the brain pass through before forming the optic nerve. The image is a powerful snapshot of the extreme intricacy of the eye's retina. It was taken by Hassanain Qambari, assisted by Jayden Dickson, both of whom are at the Lions Eye Institute in Western Australia.

Qambari's research focuses on detecting and finding treatments for diabetic retinopathy, in which high blood sugar levels cause blood vessels in the back of the eye to swell and leak, resulting in blurry vision and, sometimes, blindness.

He said he entered the contest to showcase how complex this vascular network is. Locating the microscopic vessels was a "technically demanding challenge", he added.

Another rodent features in the photo to the bottom left – of a mouse embryo – taken by Grigorii Timin and Michel Milinkovitch at the University of Geneva, Switzerland. Achieving seventh place, the picture was captured using a technique called light sheet fluorescence microscopy.

Above it, winning an Image of Distinction award, is Sébastien Malo's close-up of a crab spider (*Thomisus onustus*), the females of which can change colour between yellow, pink and white to blend in seamlessly with the flowers on which they both stalk prey and hide from predators. ▮

Gege Li

Editor's pick

On the best route to decarbonising quickly

30 September, p 37

From Ben Haller, Ithaca, New York, US

Former UK government adviser Simon Sharpe is dismissive of carbon taxes as a means of tackling the climate crisis, instead urging investment "in new technologies and new systems".

But these aren't mutually exclusive. He himself says that we need "investment in targeted subsidies so that these solutions can take root while they are still more expensive than the fossil fuel alternatives". That is the point of a carbon tax – to level the playing field by forcing fossil fuels to pay for their negative externalities.

And achieving that with a carbon tax is more even-handed than doing it with targeted subsidies: his approach needs central planning, choosing which new technologies merit subsidy and which don't, whereas a carbon tax allows the free market to perform its magic much more efficiently. We don't know enough to make such central-planning choices accurately.

From Robbie Morrison, Berlin, Germany

In his call to rethink how climate policy is communicated to policymakers, Sharpe fails to mention the integrated assessment models (IAMs) that have underpinned Intergovernmental Panel on Climate Change reporting to governments for three decades. These are technology focused and highly dynamic. They track the unit cost of existing technologies against uptake, assess speculative technologies and contain detailed climate descriptions and stress mitigation. These IAMs include everything that Sharpe argues is missing from the net-zero debate.

Conversely, the risk-oriented formulation he advocates is more suited to eliciting adaptation. On the tough question he raises about individual carbon footprints, recent IAM studies show that climate-friendly lifestyles can radically ease the challenge of reaching net-zero by 2050. Individual actions can thus help derisk protecting the climate.

AI whodunnit had a fatal flaw

7 October, p 20

From Dave Neale, Bedford, UK

I agree that new AIs have shortcomings. When I asked ChatGPT to write a story in the style of Agatha Christie, it wrote pages of frighteningly realistic text until it broke the most basic rule of crime writing: it told me that it was the gardener who did it. The problem was, the gardener hadn't previously appeared in the story!

Evolution could avert a future natural disaster

30 September, p 9

From Geoff Harding, Sydney, Australia

You report on a study that predicts nearly all mammals will go extinct in 250 million years as continents recombine and the climate shifts.

However, I assume that the changes will occur so slowly as to allow considerable time for evolution. Humans may be long gone, but, as a last resort, many mammal species might adapt to spend a major part of their lives underground or in the oceans.

From Thomas Smith, Saint-Louis, France

Researcher Alexander Farnsworth anticipates that, due to natural processes, atmospheric carbon dioxide will reach levels incompatible with mammalian survival in a quarter of a billion years. He hopes that "we'd be a space-faring civilisation by that point". But the technical challenges in managing atmospheric CO_2 levels are trivial compared with those of human interplanetary flight.

The UK just exported its industrial emissions

7 October, p 12

From Graham Griggs, Leigh-on-Sea, Essex, UK

Concern over China's carbon emissions misses a key point. In the 1950s, when vehicle use was really beginning to take off, British models were made from steel produced domestically and from locally mined iron ore and coal.

Now, the same car could be made from ore and coal mined in Australia then sent to China's steel mills, with the steel sent to mainland Europe and turned into cars for export to the UK. We in the UK may pat ourselves on the back for cutting carbon emissions by closing our heavy industries, but we are responsible for the far greater emissions from the transnational production of modern cars, even though that carbon isn't emitted here.

If a lack of free will is good enough for them...

30 September, p 32

From R. C. Gibson, Irvine, California, US

I offer further arguments against the existence of free will. First of all, two of the greatest minds to have ever lived, Bertrand Russell and Albert Einstein, scoffed at the very existence of free will.

Secondly, many parents of more than one child will attest to how different their offspring are and how their personalities stayed the same from toddler to adult. We must acknowledge Friedrich Nietzsche, who told us that we all become who we are. Free will is just wishful thinking.

From Bill Schohl, Los Angeles, California, US

Are the forces of evolution so powerful and compelling that they negate free will? Or are they so powerful and compelling that they create free will? Either you have no choice or you have no choice but to have choice.

Where are all the old 'how to write in code' guides?

23 September, p 40

From Terry Cannon, Lewes, East Sussex, UK

Your fascinating article about deciphering historical documents written in code made me wonder where the code-breaking sources that must have been needed by the senders and recipients of these documents are. Have none been found? No worksheets where recipients struggled to "translate" what they were given? Are there no books with guidance on how to encrypt messages, or did each author invent their own method?

Welcome clarity on human microbiome

7 October, p 30

From Ursula Arens, London, UK

Thank you for putting aside the hyperbolic, catchy factoids on the gut microbiome to give clear comment. There are trillions of residents in our colons, but we are still in the very early stages of defining which microbial make-ups are better or worse.

Greater microbial diversity appears to be beneficial, and this is supported by diets with fibre, or prebiotics, from a variety of plant foods: fruits, vegetables, berries, wholegrains, legumes and pulses. Microbes consumed in foods, known as probiotics, don't affect diversity in the colon, and the European Food Safety Authority hasn't approved any health claims for probiotic products.

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Missing stars

A disdain for misogyny shines through in this rich history of women's underappreciated contributions to astronomy, finds **Bethan Ackerley**

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Astronomer Annie Jump Cannon, pictured around 1920

Book

Her Space, Her Time

Shohini Ghose

MIT Press

IT IS perhaps natural, when reading *Her Space, Her Time: How trailblazing women scientists decoded the hidden universe*, to make comparisons with *Hidden Figures*. After all, the book's marketing makes it clear that it was influenced by Margot Lee Shetterly's acclaimed account of Black women at NASA during the space race. And yes, it leans on a similar metaphor, speaking of "invisible stars here on Earth" who shed light on the unseen cosmos.

But *Her Space, Her Time* – by Shohini Ghose, a quantum physicist at Wilfrid Laurier University in Canada – treads new ground and is wider in scope than its forebear. Each chapter focuses on an area of physics or astronomy to which women made huge, underappreciated contributions: radioactivity, the big bang theory and parity violation, to name just a few. Some of those included have a degree of fame, such as Henrietta Leavitt, whose work lets us measure the distance of celestial objects. Others are barely known, such as Bibha Chowdhuri, a pioneer of cosmic ray research.

And some are sadly nameless. One chapter focuses on Mary Golda Ross, the first Native American woman to hold an advanced mathematics degree. Ross's talents were crucial to the development of the Agena rocket, which came to be one of the most flown rockets in the world. But here, we also learn about the Navajo women at the heart of the electronics revolution. The firm Fairchild Semiconductor built a plant in Shiprock, New Mexico, in 1965, employing hundreds of Navajo people, mainly women, to handle the complex components that would be used in NASA's space programme. They developed techniques that lowered the failure rate of chips to less than 5 per cent, a quarter of that of any other factory, but they were paid less than minimum wage.

> **"Much of the early funding for astronomy in North America came from women, such as Mary Anna Draper"**

It is moving to see the connections between women. We learn that much of the early funding for astronomy in North America came from women, such as Mary Anna Draper, whose money enabled researchers at Harvard College Observatory in the late 19th century to create a comprehensive record of thousands of stars.

This work was underpinned by the calculations of women like Annie Jump Cannon and Williamina Fleming. Working with the observatory's director, Edward Pickering, Cannon reconciled two systems of stellar classification (one spearheaded by Fleming, the other by Draper's niece, Antonia Maury) to form the Harvard Classification Scheme. Setting out the star classes O, B, A, F, G, K and M, this was first published in 1901. The astronomer Cecilia Payne-Gaposchkin showed in 1925 that this sequence decreases in temperature.

The long road to the Harvard Classification Scheme typifies how women scientists have bridged chasms of misogyny through their intellect and collaborative spirit, but it also reveals how deep those fissures run. Soon after the scheme was published, a mnemonic to remember the sequence emerged: "Oh, Be a Fine Girl, Kiss Me!" As Ghose puts it, "a brilliant scientific achievement by a woman, building on two decades of work by women, most of it funded by women, turned into a ridiculous request to all women". The phrase is still in some textbooks today.

Just as women astronomers have been refused authorship, awards and prestigious academic positions in life, they have also often been denied the typical honours afforded to leading researchers in death, such as having cosmic phenomena named after them.

Ghose reminds us that the cheapening of women scientists' achievements (or their misattribution to men) has come to be known as the Matilda effect, after 19th-century suffragist Matilda Gage, who first drew attention to it – a rare case of a woman getting her due.

This is just one strand of a rich history Ghose has assembled. She walks a difficult tightrope, deftly explaining tricky concepts while providing enough detail to keep experts entertained. The book is almost always interesting, and the few drier patches are livened up by her pointed asides, in which she lets her disdain for misogyny past and present shine through. When recalling her amazement at the launch of the James Webb Space Telescope in 2021, Ghose wonders "what Henrietta Leavitt would have wanted to observe using this incredible new telescope. I also wonder why the telescope does not carry her name."

So yes, it is clear that *Her Space, Her Time* is part of a lineage of books like *Hidden Figures* – important, often thankless works that don't always make household names of their subjects. But just as women like Cannon conducted research that other women built on, so, too, has *Her Space, Her Time* made an important contribution to this chain of histories, one that will no doubt lead to a clearer view of the science that lit up our universe. ▮

Taking a hammer to it

An eye-opening read traces today's collective rage against big tech back to the Luddite uprising, says **Jeremy Hsu**

Book

Blood in the Machine

Brian Merchant

Little Brown

NOBODY likes being described as someone who mindlessly opposes technology and is doomed to irrelevance. So imagine how the Luddites would feel knowing their name has been smeared with that meaning over the past 200 years.

The Luddite movement, which challenged factory automation in England at the start of the industrial revolution, was far more reasonable and complex than the bogeyman conjured up by governments and businesses, writes Brian Merchant, technology columnist at the *Los Angeles Times*. In his book *Blood in the Machine: The origins of the rebellion against big tech*, Merchant unspools a myth-busting historical tale interwoven with pointed comparisons to how modern tech giants are eroding workers' collective rights and prosperity through an algorithm-driven gig economy, and attempting mass automation of jobs using robots and artificial intelligence.

Instead of naively raging against all machines, the 19th-century Luddites were motivated by clear-eyed recognition of how some local entrepreneurs – whom Merchant describes as the "first tech titans" – deployed water- and steam-powered technologies such as power looms to churn out lower-quality yarn and cloth, replacing skilled artisan weavers with low-paid factory workforces doing dull and dangerous tasks.

Those entrepreneurs knowingly chose to adopt automation for the sake of maximising business profits while destroying the "flexible and family-oriented" cottage industry lifestyle that had sustained hundreds of thousands of weavers and their families. "If the Luddites have taught us anything, it's that robots aren't taking our jobs," writes Merchant. "Our bosses are."

Facing mass unemployment, workers responded with a resistance movement focused on breaking machines with hammers. But such action only came after years of peaceful work strikes and local negotiations with factory bosses, along with petitions to the Crown that mostly went unheeded.

Luddites wore masks to hide their identities during raids and wrote anonymous warning letters signed "General Ludd" or even "King Ludd" – essentially a "powerful nineteenth-century meme" based on the legend of a young cloth trade apprentice named Ned Ludd, who supposedly smashed his employer's knitting frame before hiding out in Sherwood Forest like Robin Hood, writes Merchant.

Blood in the Machine traces the Luddite movement's spread from Nottingham in central England northwards, starting in 1811. The British government eventually suppressed the Luddites by making machine-breaking a capital offence under the law and using military force. Still, Merchant finds reasons for optimism in how their actions slowed automation in certain regions for years, buying time for political reforms to restore some protections.

A revived spirit of Luddism may be more necessary than ever in the 21st century, when companies such as Uber and Amazon are imposing mass surveillance and a "robotic pace of work" on millions of workers, writes Merchant. He also points to how venture capitalists are backing generative AI services capable of churning out synthetic images and text in ways that undermine the livelihoods of artists and writers.

The response of modern workers has been to organise amid a growing backlash against big tech. The first draft of this history is still being written in headlines about resurgent labour unions and 2023's "hot strike summer". Nobody is smashing up data centres with hammers just yet – but the Luddites' story shows how people can be moved to violence against machines if governments and tech titans leave them with no recourse.

Workers striking today can trace the essence of their dispute back to the industrial revolution

SEBASTIAN WILLNOW/DPA/ALAMY

New Scientist *recommends*

Isabel Baldwin

Social media manager

London

This week, I went to London's Imperial War Museum to see the free exhibition **Spies, Lies and Deception**. It starts with some James Bond-style gadgets, including a lipstick with a hidden camera, a matchbox with a secret compartment and shoes that make fake footprints. I liked the "Lies and Deception" part on how armies spread disinformation, such as through a fake medical report from the second world war claiming that German wholegrain bread would cause all sorts of deadly illnesses.

I've also been watching **Chimp Empire**. Just like any good drama, this new Netflix series has stories of turf wars, power struggles and betrayal. This time, though, the stars are chimps. As a deep look at a chimpanzee tribe in Kibale National Park, Uganda, it gives a real insight into how the chimps function as a society: how they communicate with each other, protect their land, raise their children and mourn their dead. It's not only fascinating, but it's also a beautiful watch.

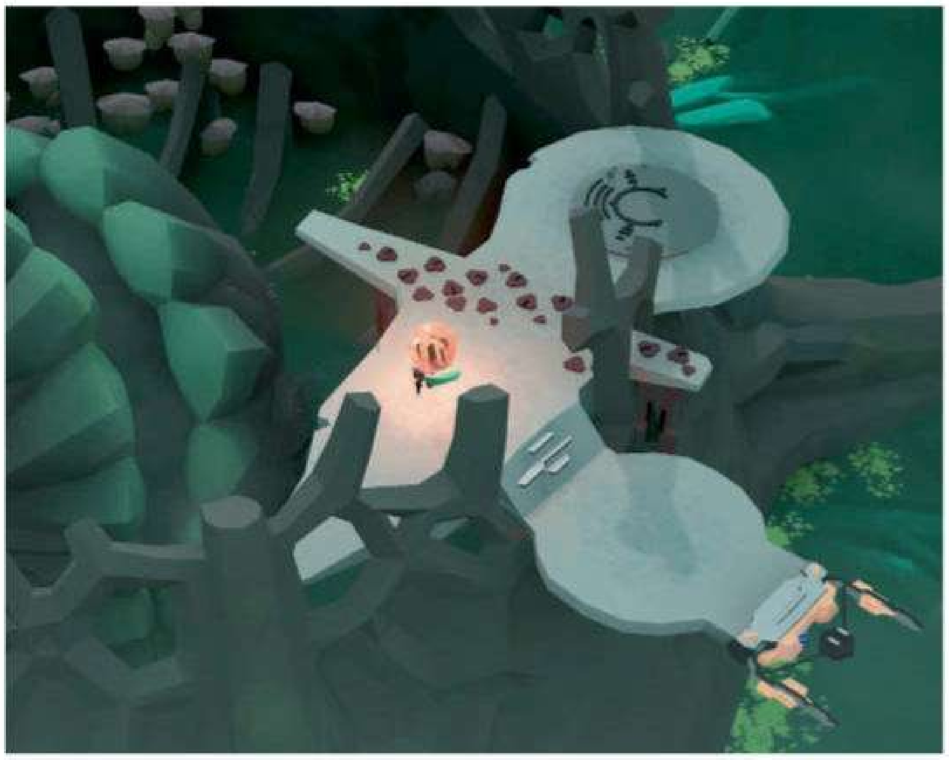
NETFLIX

The games column

Worlds within worlds

Interesting, mind-bending puzzles abound in *Cocoon* – some so clever they will make you gasp. With visuals reminiscent of H. R. Giger, don't miss out on one of the biggest gaming treats of the year, says **Jacob Aron**

Jacob Aron is *New Scientist*'s news editor. Follow him on Twitter @jjaron



ANNAPURNA INTERACTIVE

***Cocoon*'s visual style is that of H. R. Giger let loose with a colour palette**

I AM a sucker for video games that explore unusual geometries, creating fun by playing with the nature of space itself. It is no surprise, then, that I loved *Cocoon*, which turned my brain inside out, upside down and through other spatial transformations probably best not mentioned outside of advanced, degree-level maths.

The game starts with a humanoid-looking insect being birthed from a cybernetic cocoon. You take control of it and wander around a desert landscape dotted with equipment that is a blend of biological and mechanical – *Cocoon*'s visual style is that of artist H. R. Giger of *Alien* fame let loose with an actual colour palette. With no dialogue, there is little story to speak of, but the atmosphere is incredible, whether you are traversing paths that look like delicate insect wings or watching a beetle-inspired door to a new location gradually unfurl.

Early levels see you solve a variety of puzzles involving accessing and hitting switches that at first seem out of reach, but after besting an angry wasp robot, *Cocoon* starts revealing its hidden treasures.

The game's core mechanic involves picking up glowing spheres that give you powers that help you navigate the world you initially find yourself in, such as revealing hidden paths. This gets more complex: you can also enter the spheres to uncover new worlds to explore. Crucially, you can bring one sphere into another, allowing you to exploit its power in the interior world and trace a path through interlocking spaces.

> **"You wander around a desert landscape dotted with equipment that is a blend of biological and mechanical"**

This key twist opens up a huge variety of interesting, mind-bending puzzles. Each time *Cocoon* escalated in complexity, I was taken aback by the inventiveness of the new ideas I was being asked to explore. Importantly, the game is never unfair. In a brilliant move, paths within the world that aren't relevant to the current puzzle are quietly closed off, making it clear exactly where you should focus attention. It is like the developer is sitting beside you, saying: "Don't worry about that bit, look at these bits here. Rearrange the pieces – you can do it!"

As such, I was never frustrated playing *Cocoon*, though I certainly found myself challenged on many occasions throughout the game's 4-to-5-hour duration. A couple of puzzles literally made me gasp at how clever they were, and how clever I felt when I solved them.

In fact, smart choices abound throughout. The controls are stunningly simple, with just movement and a single button for interaction. Initially, I thought this would limit the complexity of the puzzles – even the 1980s *Super Mario Bros.* gives you two buttons – but instead it means you can concentrate on figuring out solutions, rather than struggling to execute them with fiddly controls. Failing to beat a boss doesn't kill you, but boots you out of your current sphere. Again, I heard the developer: "Well, you didn't manage it this time, but have another go!" Most tellingly, the game doesn't work through all the possible permutations of its sphere powers and worlds – something a lesser developer might have felt the need to do, at the cost of quality.

It is difficult to talk about *Cocoon*'s specifics without spoiling it, but really, if I haven't sold you on this game by now, I probably never will. If so, I'm sorry, as failing to play *Cocoon* would mean missing out on one of the biggest gaming treats of the year. ▮

Game

Cocoon

Geometric Interactive

PC, PlayStation 4 and 5, Xbox One and Series X/S, Nintendo Switch

Jacob also recommends...

Game

Hollow Knight

Team Cherry

PC, PlayStation 4, Xbox One, Nintendo Switch

With more of a focus on combat and exploration, this isn't really a puzzle game in the same way as Cocoon, *but its world design shares a love of creepy crawlies.*

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Brain bank

Your brain can build a buffer against dementia and cognitive decline. We are finally getting to grips with the mechanisms of this cognitive reserve, opening up new ways to boost it, finds **Anthea Rowan**

IF I never thought about dementia before, I thought of little else after the condition manifested in my mother. The odd thing was that dementia – Alzheimer's disease, in her case – didn't occur to me until she asked, out of the blue, when we had first met.

My failure to recognise the extent of her cognitive decline was born partly of denial, but also because she was doubtless compensating for her galloping brain damage, taking cerebral detours around the potholes dug by her condition. After all, she had done this before. Following a stroke four years previously, she had lost the ability to read; after much hard work, she learned the skill again.

So how come this ability to adapt, which seemed to sustain her after her stroke, was unable to withstand the pathology of dementia? This also made me think about my own resilience to cognitive decline and what, if anything, I could do about it.

We have known for almost three decades that some peoples' brains can function normally even when riddled with the plaques and other damage associated with dementia, due to an enigmatic capacity called cognitive reserve. Yet despite growing evidence of its importance, it has been challenging to pin down how this quality operates in the brain. Now, we are finally beginning to understand the mechanisms that underlie cognitive reserve, opening up possible new dementia treatments and fresh ideas about how we can protect our thinking abilities into old age. And it turns out that obsessing about learning another language or doing a daily crossword might be missing the bigger picture.

The concept of cognitive reserve arose nearly 30 years ago when Yaakov Stern, a neuropsychologist at Columbia University in New York, and his colleagues found that people with higher education or a more intellectually challenging occupation were less likely to develop Alzheimer's disease. The researchers hypothesised that the extra years of intellectual effort imparted "a reserve that delays the onset of clinical manifestations".

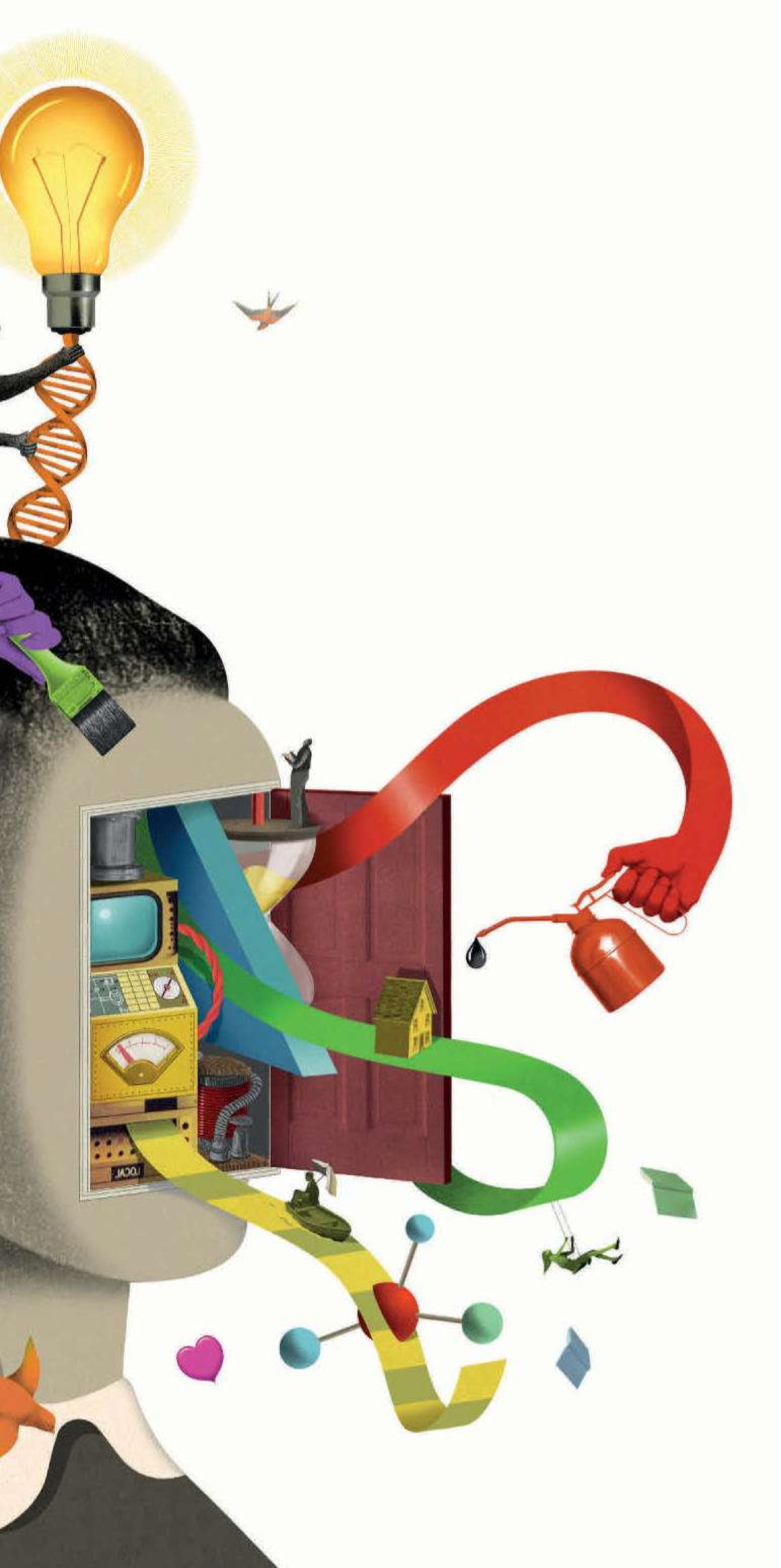
At first, the concept wasn't taken seriously. "Colleagues made fun of the idea," says Stern. "It seemed so far-fetched that something like education could counter the plaques and tangles of Alzheimer's."

Mental reserves

Stern called this capacity "cognitive reserve" to differentiate it from a related concept of "brain reserve" that had been defined a few years previously by Robert Katzman, then at the University of California, San Diego. He studied the brains, post-mortem, of elderly residents of a care home and found that some contained a high degree of plaques associated with Alzheimer's, even though the cognitive abilities of these individuals had ranked in

"Education, occupation and social engagements contribute to your cognitive reserve"

BRETT RYDER



the top 20 per cent of the nursing home's residents – as good as, or better than, those without any brain pathology. He concluded that this was due to them having bigger, heavier brains, hence a greater number of neurons and therefore more "brain reserve" to withstand the damage caused by plaques.

Brain reserve is a structural quality measured by brain volume, which gives an indication of the number of neurons and synapses – the connections between neurons through which information flows.

Stern likens cognitive reserve to the software of a computer – a capacity that can be upgraded throughout our lives – whereas brain reserve is the hardware.

Brain reserve was once regarded as having a fixed capacity, but this view has now changed. Not only is there evidence that our brains may be able to make new neurons throughout adulthood, but we now know that many things can influence the functioning of the brain's hardware. This has led to the recognition of a third pillar that underlies cognitive resilience: brain maintenance, which is the lifestyle or environmental factors that keep the brain in good condition.

It is the combination of cognitive reserve, brain reserve and brain maintenance that enables some individuals to preserve their thinking abilities into old age more successfully than others. "These three aspects are highly interrelated," says Dorina Cadar at Brighton and Sussex Medical School, UK.

The protective effects of this cognitive resilience have since been confirmed by multiple studies. For example, a 2020 study of the incidence of dementia followed more than 12,000 people aged 50 or over as part of the English Longitudinal Study of Ageing. It found that "many aspects, such as education, type of occupation and lifestyle choices, including leisure and social engagements", contributed to a higher level of cognitive reserve and hence a reduced risk of dementia, says Cadar.

One of the curious things about cognitive reserve, however, is that we can't see it in the brain or directly measure it, though Stern has made some progress in identifying what seem to be associated networks. Cognitive reserve is typically measured using proxies such as attainment in cognitive tests. Through this and other proxies, we have discovered a huge amount about the factors that can influence it. ›

Some of these are down to luck. Our genes, for example, play a strong role in determining our intelligence, and a higher IQ is associated with a higher cognitive reserve. But other factors are more malleable. Higher levels of social engagement in mid or later life, for example, are strongly linked with better cognitive performance in older age and a 30 to 50 per cent lower dementia risk.

Socialising is a mental challenge: you have to remember faces, names and the context of other people, navigate a conversation, ask questions, use humour and observe social cues, says Andrew Sommerlad at University College London. "There's a lot going on at once," he says, which stretches the brain, and it also has a stress-lowering effect. In fact, a lack of these kinds of interactions might have predisposed my mother to dementia. She was diagnosed with depression aged 38 and could withdraw from others for months on end.

Stress, obesity and poor diet can all have a harmful impact on our reserve due to the persistent inflammation they trigger, which can disrupt many of the brain's functions. "It can't use glucose effectively, nerve activity is upset," says Craig Ritchie, chief executive and founder of Scottish Brain Sciences. This also compounds the effects of "inflammaging", the low-level chronic inflammation that inevitably develops as we age.

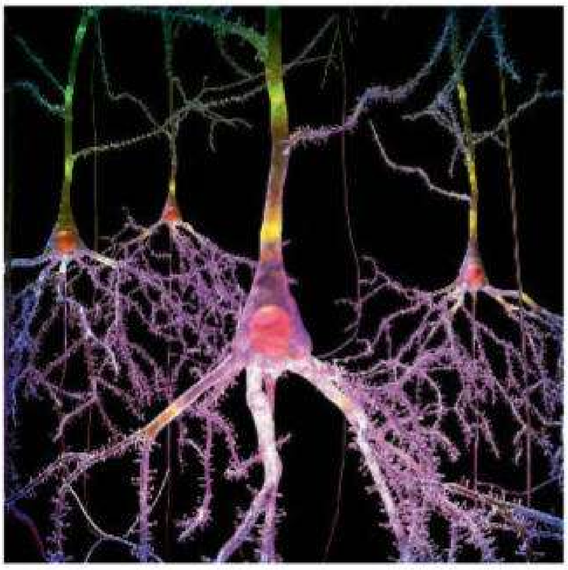
On the other hand, a good night's sleep can help our cognitive reserve. One study from earlier this year found that a particular phase of our sleep cycle, non-rapid eye movement (NREM), seems to be especially important. This may be because this phase of deep sleep is crucial for the consolidation of memories, as well as for the clearance of toxins that interfere with healthy brain functioning.

Another, perhaps unexpected, factor linked to cognitive reserve is physical activity. A 2020 study of nearly 130,000 US adults, for example, found that cognitive decline was almost twice as common among those who were physically inactive compared with people who were active. This is because the role of exercise in brain health, rather like social engagement, is multifaceted. It supports cardiovascular health and cerebral blood flow – both important for brain health – helps reduce inflammation and elevates the levels of brain-derived neurotrophic factor, a substance that has been shown to increase the size of that all-important memory centre: the hippocampus. Exercise also improves memory by promoting deep sleep.

Unsurprisingly, many more obviously cerebral activities also influence our reserve. Various studies show that speaking more than one language acts as a powerful cognitive stimulant. For example, although bilingual and monolingual people eventually have the same number of Alzheimer's disease cases, "bilinguals tend to be able to stave off these symptoms for longer," says John Grundy at Iowa State University.

"Cognitive reserve is the end point of exercising your brain throughout life"

But don't rush to learn a new language just yet. What really seems to matter is strong mental engagement and focus on challenging activities, not any specific activity per se. A 2015 study, for example, used functional MRI scanning to compare the brain activity of US participants, aged between 60 and 90, before and after engaging in focused effort over 14 weeks in quilting or digital photography. It found that their brains' neural networks operated more efficiently, adopting more youthful-like patterns compared with those of a control group that didn't take part in these activities. The effect lasted at least a year.


RUSSELL KIGHTLEY/SCIENCE PHOTO LIBRARY

Nerve cells have protusions called dendrites (shown in purple) that collect and transmit information

Other studies show that learning and engagement contribute to the preservation of brain volume and prevention of shrinking of memory centres. For instance, a 2023 Swiss study of people aged between their early 60s and late 70s revealed that a six-month music intervention – whether playing it or listening to it – improved memory and increased both neuroplasticity and volume of grey matter, the brain tissue packed with synapses and neuron cell bodies (which are the portion of a cell that contains its nucleus).

Neuroplasticity derives from the brain's innate ability to reorganise itself in order to accomplish tasks in the most streamlined way. As you become more practised at a thing, says Pamela Almeida Meza at University College London, you become more efficient and trim networks. Cognitively demanding tasks strengthen the underlying neural pathways and create alternate pathways that mitigate loss of function due to progressive brain degeneration. We used to think that neuroplasticity was a privilege of youth, she says. "But evidence over the last few years shows there is neurogenesis during adulthood and old age, just not at the same rate."

We need to think of cognitive reserve beyond just education and professional success, says Sommerlad. It is, ultimately, the end point of exercising your brain throughout your life, partly through education (the most studied of all proxies), but other things too: a healthy lifestyle, physical activity, socialising and mentally taxing activities. "There is no silver bullet to building cognitive reserve," says Grundy.

None of this, however, explains the neural underpinnings of our brain's resilience to dementia. Ultimately, this all comes down to one thing: synapses.

In recent decades, it has become clear that Alzheimer's disease is linked to the loss of synapses, due to the degradation of dendritic spines that protrude from neurons to make connections with other neurons. Dendritic spine density is critical for information processing, memory and learning. One crucial insight is that dendritic spine density is maintained in people whose brains are affected by Alzheimer's disease pathology, but who are cognitively normal. . "The preservation of synapses strongly correlates with cognitive resilience to Alzheimer's disease," says Patricio Opazo at the University of Edinburgh, UK. "The question remains as to how synapses are preserved in cognitive-resilient individuals."

It could be that those with more synapses to start with are protected from dementia. However, Jeremy Herskowitz at the University of Alabama at Birmingham thinks that our cognitive resilience mechanism is a more dynamic process than this. "It's actively regenerating," he says. "If something bad happens, like the accumulation of Alzheimer's pathology, then your brain remodels itself to continue to work normally. It's not just that you have a higher starting point. The brain has got its own coping mechanism."

Some fascinating new research is revealing how this regeneration process works. Dendritic spines come in different forms, including thin ones – hypothesised to be the most plastic type, necessary for learning new things – and mushroom-shaped ones, a more stable form thought to be involved in the retention of long-term memories. Intriguingly, the number of thin spines is reduced in people who have cognitive impairments through Alzheimer's disease, but maintained in those with normal cognition, despite the pathology of the disease.

Even more surprisingly, it was found that spines are longer in people who are cognitively normal, a discovery that Herskowitz says "is probably one of the most profound moments in my career". There is now a lot of data to suggest that increased length in thin spines improves resilience to Alzheimer's disease, he says. What's more, this research has identified some of the factors that regulate spine density and length in humans, making them a potential candidate for therapeutic intervention.

One of these is neuritin (NRN1), a protein secreted by neurons and found throughout the brain. NRN1 seems to act as a mediator of cognitive resilience to Alzheimer's disease. Evidence for this comes from the Religious Orders Study of older Catholic brothers, nuns and priests from across the US who agreed to undergo yearly cognitive testing and brain donation after death. When Herskowitz and his colleagues analysed 250 people from this study, they found that higher levels of NRN1 in later life were associated with better cognitive abilities and greater spine density. "It looks like this protein is very supportive of neurons. It's almost like a vitamin for neurons," he says. Earlier this year the researchers identified another protein, Twinfilin-2, that influences spine length.

SERGI REBOREDO/VW PICS/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES

Studies of the brains of nuns have been crucial for our understanding of resilience to dementia

Neural supplement

But how exactly do these factors help build cognitive reserve? The idea is that activities that stimulate cognitive processes in the brain increase levels of proteins such as NRN1, which, in turn, helps to create new synapses or preserve existing ones. "I think the mechanism works similarly to your muscles and exercise. So, throughout life, if you continue to read and stay intellectually and socially engaged, you stimulate your mind much like you would stimulate your body doing exercise," says Herskowitz. The inherent plasticity of your neurons needs to be worked through those kinds of mental stresses, he says. "If you don't stimulate your brain and stimulate your neurons to think, then you'll lose those synapses naturally, even without the effects of Alzheimer's disease."

It is very early days, but Herskowitz envisages that, one day, NRN1 could be given as a supplement to support brain function, and as an alternative way to forestall the pathological effects of Alzheimer's disease and dementia to the current approaches, which are mainly focused on eliminating plaques and protein tangles in neurons.

Others agree with this view. "Rather than focusing on eliminating pathology or what led to it – which has been quite unsuccessful, to put it mildly – I think we should be boosting the protective mechanisms implemented by the brain to cope with pathology in the first place: synaptic compensation, repair and regeneration," says Opazo.

This is promising for the future, but it is also important to recognise a sobering reality to cognitive reserve: while a higher reserve correlates with later onset of cognitive impairment, it also tends to lead to a steeper decline once the pathology overwhelms a person, says Stern. This is what seemed to happen to my fiercely intelligent mother, who was in excellent physical health until her stroke, could speak English and French and regularly tackled cryptic crosswords.

As for myself, I will try to add a bit to my reserve each day – through exercise, socialising or writing articles like this. But I am also hoping that our new understanding of how mental effort can build connections between neurons might one day offer new ways to supplement my cognitive bank account. ∎

Anthea Rowan is a freelance writer based in Tanzania

What is killing urban trees?

The trees that line our city streets are dying in droves. Boosting their microbiomes could help them live longer, says **James Dinneen**

IF YOU have ever walked down a tree-lined street on a hot day, you know the value of urban trees. They provide shade and respite from the concrete jungle. Some, like the great trees of London, a few of which are centuries old, are simply magnificent to behold. City trees have a range of less obvious benefits, too, from flood control to improving our mental health. It is no wonder, then, that around the world efforts to expand urban forests are growing. But there is a problem.

Take Boston, Massachusetts, where researchers have scrutinised the local trees for decades. There, around 40 per cent of saplings die within seven years of planting, far too early to realise their benefits. It is the same elsewhere. In New York, more than a quarter of trees planted in 2009 were dead within nine years. Despite planting drives, urban tree cover across the US fell by about 36 million trees per year between 2009 and 2014. What is going on?

We know these trees face unique challenges, from excess warmth due to the urban heat island effect to a surfeit of nutrients from dog urine. Poor, under-resourced management is also a factor. But now, emerging research suggests that all these may be the roots of another problem for urban trees: unhealthy microbiomes. Without the right kind of microbial communities, they may be more susceptible to the stresses they face in cities, and things look even worse for the most isolated or “lonely” trees.

The good news is that improving trees’ microbiomes could help them live longer – to the benefit of all city dwellers.

The majority of the human population are now urbanites, and the urban environment is forecast to be three times the size it was at the turn of this century by 2030. The importance of urban forests is growing accordingly. For instance, city trees help reduce the urban heat island effect by limiting the amount of the sun’s radiation absorbed by the built environment, as well as cooling the surrounding air. Trees reduce runoff and associated flooding by intercepting rain. They also clean pollution from the air and water, serve as habitat for a host of urban wildlife and store carbon.

While city authorities have long recognised these benefits, most haven’t invested enough to maintain their urban forests, or done so equitably. In the US, decades of discriminatory planning practices have left

IAN DAGNALL/ALAMY

The trees in Boston are among the most studied in the world

many neighbourhoods that are inhabited primarily by people of colour with fewer trees than whiter neighbourhoods. Low-income neighbourhoods in the US have 15 per cent less tree cover on average than wealthier ones, and the UK has similar disparities. Hotter than average temperatures in these neighbourhoods are largely a reflection of their lack of trees.

Growing recognition of those inequities, along with rapid urbanisation and billions of dollars in climate change-related funding, has spurred urban authorities to redouble efforts to maintain and expand urban forests. Many local residents have also got involved (see "Help your street trees", page 36). However, if a lot of these trees die within a few years of planting, much of this effort is wasted. "Trees need to get really big to benefit people," says Jennifer Bhatnagar at Boston University. It takes some 10 years after a specimen is planted for it to become established and grow a cooling canopy, she adds. Depending on the city and the species, a tree must survive two or three decades just to offset the carbon emissions produced by planting and maintaining it. A city of saplings is no replacement for a long-lived urban forest. This is why early mortality among city trees is so concerning.

> **"In cities, there is a breakdown in the relationship between soil fungi and their tree hosts"**

To tackle the problem, we must first understand why trees are dying. But making sense of the fate of millions of them in complex urban ecosystems isn't straightforward. "It's very hard to figure out what's happening," says Bhatnagar. Not only are there classic ecological factors like heat and drought; there are unpredictable human elements, too. Soil can be compacted or contaminated. City air is polluted with particulates, ozone and other gases. Humans may introduce invasive pests and pathogens. Management is also a big factor, with trees planted in poor soils, then underwatered, over-pruned, vandalised or felled to make way for developments. "In other areas of ecology, you don't even think about people," says Bhatnagar.

One clue to why city trees die is when they tend to die. There is a general pattern that can be seen clearly in the closely studied trees of Boston. When Lucy Hutyra at Boston University and her colleagues compared thousands of the city's trees with their rural counterparts, they found that both died at high rates when young. Urban trees were also more likely to die when they are bigger, whereas mortality rates fell in rural trees the longer they survived.

This suggests different drivers of tree death in urban and rural settings, says Bhatnagar. She thinks that older city trees regularly succumb to over-zealous pruning or removal because they are deemed to be in the way or to pose a hazard. For younger urban trees, she suspects their deaths are often due to a failure to establish roots and access water. (Conversely, in rural environments tree seeds germinate profusely, but the population of saplings is naturally culled as they compete for light and nutrients.) City trees' failure to establish roots may be caused by stressors unique to cities, ›

> **"An unhealthy microbiome could affect the immune systems of city trees"**

such as densely packed soils, excess nutrients and hotter temperatures.

New evidence, meanwhile, points to a problem with the microbes that live on and inside the roots of urban trees. Bhatnagar, a microbial ecologist, is a pioneer of this research. Until she learned about the plight of Boston's trees, she hadn't thought much about urban ecology. But in 2018, she started working with Hutyra's group to explore whether problems with the microbiomes of city trees might be playing a role in driving high mortality rates. "It's the most interesting science I've ever done," she says.

One finding that intrigued her was from a small study conducted in Ontario, Canada, in 2009. The researchers found that the roots of urban trees were colonised by substantially fewer symbiotic fungi than comparable rural trees, and that there were fewer species present. Such mycorrhizal fungi are known to form mutualistic relationships with many species of plant. The fungi encase or penetrate tree roots with thin filaments to exchange nutrients such as nitrogen and phosphorus in return for sugars from the plant. They can also form underground mycorrhizal networks, which may help trees to share nutrients with each other through a "wood-wide web" of molecular exchange. Some researchers have argued – though not without controversy – that this is evidence of trees helping or communicating with one another.

Bhatnagar thought the finding in Ontario was striking. "It's a very clear impact of a city on an organism," she says. But no one had followed up to see if the effect was more widespread, or what the consequences might be for tree health. So, to get a more complete view, she and her colleagues looked at data on the soil microbiome of eight urban and rural forest plots in Massachusetts. They focused on ectomycorrhizal fungi or "ectos", ones that sheathe the exterior of roots in some tree species.

Unhealthy relationship

Unexpectedly, the study, published in August, found that urban forests in Boston had more of these fungi in the soil than rural forests did. However, as in Ontario, there were fewer fungi colonising the tree roots. The researchers interpret this as evidence of a "breakdown" in the relationship between the fungi and their tree hosts. "In cities, the rules are broken for how microbes interact with trees," says Bhatnagar. She thinks this could be due to excess nitrogen in urban soils, both from pollution and from hotter temperatures favouring bacteria that fix nitrogen in soil. "If there's tons of free nitrogen in the soil, the plants will kick off the ectos," she says.

As-yet-unpublished research by Anne Pringle at the University of Wisconsin-Madison and her colleagues seems to back up this idea. In the very different setting of Bogotá, Colombia, Pringle says they are finding that trees growing in parks have fewer symbiotic fungi – both ectomycorrhizal and

Help your street trees

Many cities are planting trees to expand their urban green spaces, but there often aren't enough resources to ensure these trees are properly maintained. "It's really the people in the community who are going to keep the trees alive," says arborist Claire Corcoran at Speak for the Trees, a non-profit organisation working to expand Boston's green canopy. It is likely that your town or city has "adopt-a-tree" programmes or local volunteer groups with specific ideas and opportunities to care for urban trees. But Corcoran suggests some general ways you can help:

- **Trees need watering for up to five years to become established, although be careful not to overwater them.**
- **Densely-packed soil can make it harder for tree roots to expand and for water to reach them. Creating a small barrier so that people don't walk or cycle over roots can help.**
- **Excess nutrients from dog urine and faeces, or from trash, can pollute the soil. Avoid contaminating soil around trees and keep tree pits free of rubbish.**
- **Covering soil in mulch can help it retain water and slows nutrient inputs.**
- **Roots also need oxygen, so gently rake soil around street trees to increase aeration.**
- **People treat trees better when they understand the benefits they provide, so spread the word.**

A bit more care could boost the number of city trees that survive

RICHARD LEVINE/ALAMY

RICHARD BAKER/IN PICTURES VIA GETTY IMAGES

Bigger city trees are more likely to die than less mature specimens

endomycorrhizal ones, which penetrate tree roots – compared with trees growing in tropical forests outside the city. However, the microbiomes of street trees growing in pits surrounded by concrete are comparable with those of rural trees. Unlike soil in parks, which may more often be subjected to nitrogen-rich dog urine, "the hard surfaces don't get peed on", says Pringle.

The consequences of lower fungal colonisation rates on tree health, if any, aren't yet clear. Miranda Hart at the University of British Columbia in Canada says it would be premature to draw a link between changes in microbiomes and higher mortality of trees in urban forests. "We don't know what these conditions are doing to [large organisms], let alone what they're doing to micros," she says. But, she adds, these findings hint at yet another way in which urban environments can undermine complex ecological interactions.

Pringle is more concerned. "It is a sign of trouble," she says. The loss of the fungal sheaths around roots could expose trees to more microbial pathogens, for instance. Indeed, Bhatnagar's group has found that hotter, drier soils at the edges of fragmented forests have a higher abundance of pathogenic microbes and a lower abundance of symbiotic fungi. An unhealthy microbiome could also affect the immune systems of city trees and make them less resilient to heat and drought. But if missing fungi and other microbes are part of the problem with urban trees, they could also be part of the solution.

One researcher exploring this possibility is Bhatnagar's colleague Vanessa Harden at Harvard University. After reading about ecologist Suzanne Simard's groundbreaking work on mycorrhizal networks of old-growth forests, she wondered if she could facilitate such connections among isolated city trees. In a greenhouse at the Harvard Forest research station in western Massachusetts, she and her team have set up simulated sidewalks in the form of long wooden boxes, with soil conditions mimicking those in Boston. First, Harden plants white oak saplings at either end of each box, then, wearing latex gloves to avoid contamination, she adds a handful of extra soil collected from a stand of oaks at the Harvard Forest to one of the trees. This inoculates its roots with an intact community of fungi. Between the trees, she makes a "soil conduit" – a strip of loosened soil that should make it easier for the roots of both trees to spread.

Harden hopes to demonstrate that the mycorrhizae will colonise the first tree and spread through the conduit to the second, with health benefits for both. If the treatment works, city trees separated from others might benefit from soil conduits cut through roads or sidewalks. By her estimate, New York City alone has around 300,000 such "lonely" trees. "We have people plopping down trees without understanding what they need," she says.

After planting, young urban trees often fail to establish healthy roots

MIKHAIL OLYKAYNEN/ALAMY

Alongside Harden's team, Bhatnagar and a handful of other researchers have planted saplings in pots for a parallel experiment. The idea is to test how inoculating the plants with different types of urban and rural soils, each with distinct microbiomes, affects the growth and health of the tree. The results could inform Boston's tree-planting efforts and help correct what Bhatnagar sees as the "Home Depot-isation" of tree planting: spraying fertiliser and fungicide on any old soil and plonking in a tree.

Neither experiment will have clear results until 2025. However, research suggests that inoculating trees with native fungi and other microbes can improve growth and health, at least in non-urban settings. One Texas-based company called Funga is now using the microbes that produce the best results to make trees on a pine plantation grow bigger and faster. In Bogotá, Pringle is also experimenting with inoculation and says her group has found that trees treated with native soils and fertiliser grow best. However, she adds that one major challenge with this method is access to native soil, which can't yet be cultivated and instead must be collected from intact forest.

Hart thinks inoculation could help urban trees, but is sceptical that it would ever be enough to address the larger-scale issues that disrupt urban soil microbiomes. "We have to fix these problems if we want the microbes to survive," she says. "We need more plants and less concrete, and fewer cars."

Nevertheless, Bhatnagar believes these approaches are worth a try, given the desire to expand urban forests. "Folks are desperate," she says. "They don't want to go through the process of greening a space just to then see it fail." ▮

James Dinneen is a New York-based environment reporter at *New Scientist*

BETH HOECKEL

Seven wonders of the Milky Way

Astronomer **Matthew Bothwell** is your guide on a tour of our galaxy's most spectacular, revelatory sights

OVER the past decade, spacecraft have beamed back reports from some truly awe-inspiring destinations within our solar system. Rovers have revealed vast river channels carved by ancient floods on Mars. Probes have zipped through the turbulent geysers erupting from Saturn's icy moon Enceladus. We have even flown past the frigid mountains of Pluto. But what if we could extend our horizons further – much further?

Let's imagine that we could roam across the Milky Way on a sightseeing trip like no other. Where would I take you? Well, supermassive black holes, strange, pulsating stars and exotic Earth-like worlds are on the itinerary for starters. Aside from the sheer spectacles we'll witness, we'll discover how visiting these space oddities might offer clues to some big mysteries – from how the first stars formed to what is producing weird radio signals from outer space and whether there is life beyond Earth. Here, then, is my guide for the discerning galactic tourist.

ESO/M. KORNMESSER

An artist's impression of a landscape on Proxima Centauri b

S1 stream

Watch a passing parade of stars bursting with dark matter

To begin our journey, we'll jump into a river of stars that loops right past our front door and across the entire Milky Way. To truly appreciate the S1 stream, we have to recalibrate our sense of scale, because its length and breadth are counted in thousands of light years. Our solar system, sat in the middle of the stream, is akin to a grain of sand in the Amazon river.

To find the source of the S1 stream, we need to turn back the clock nearly 9 billion years to our galaxy's turbulent youth. Seen from the outside, the Milky Way is surrounded by a swarm of smaller "dwarf galaxies" that curve and arc in orbits around it. But when one orbited too close, it fell victim to an act of galactic cannibalism.

This unfortunate dwarf galaxy was obliterated, but its individual stars kept ploughing through the Milky Way's interstellar medium – which is mostly empty space. Today, this extended stream of stars is still distinct. In 2017, using the Gaia spacecraft, astronomers spotted 94 stars that were moving against the grain of the Milky Way. To confirm their suspicion, they measured the chemical composition of these objects and found that they had lower levels of heavier elements, such as iron, compared with native Milky Way stars. The evidence was undeniable: the S1 stream is the stripped remains of an ancient dwarf galaxy.

It is tempting to think that travelling down the S1 stream would give us the chance to solve one of the most stubborn mysteries in physics. Dark matter was hypothesised decades ago when we observed galaxies moving faster than they should, leading us to conclude that more matter must be present, even if it doesn't interact with light. Similar measurements of star motions tell us that dwarf galaxies are uniquely rich in dark matter. So the S1 stream is primarily a river of dark matter, which happens to be hitting the solar system square in the face. But while studies show that a flyby with our best detectors would improve our prospects of identifying dark matter if it comes in the form of particles call axions, the truth is we can probably do that just as well from Earth.

Proxima Centauri b

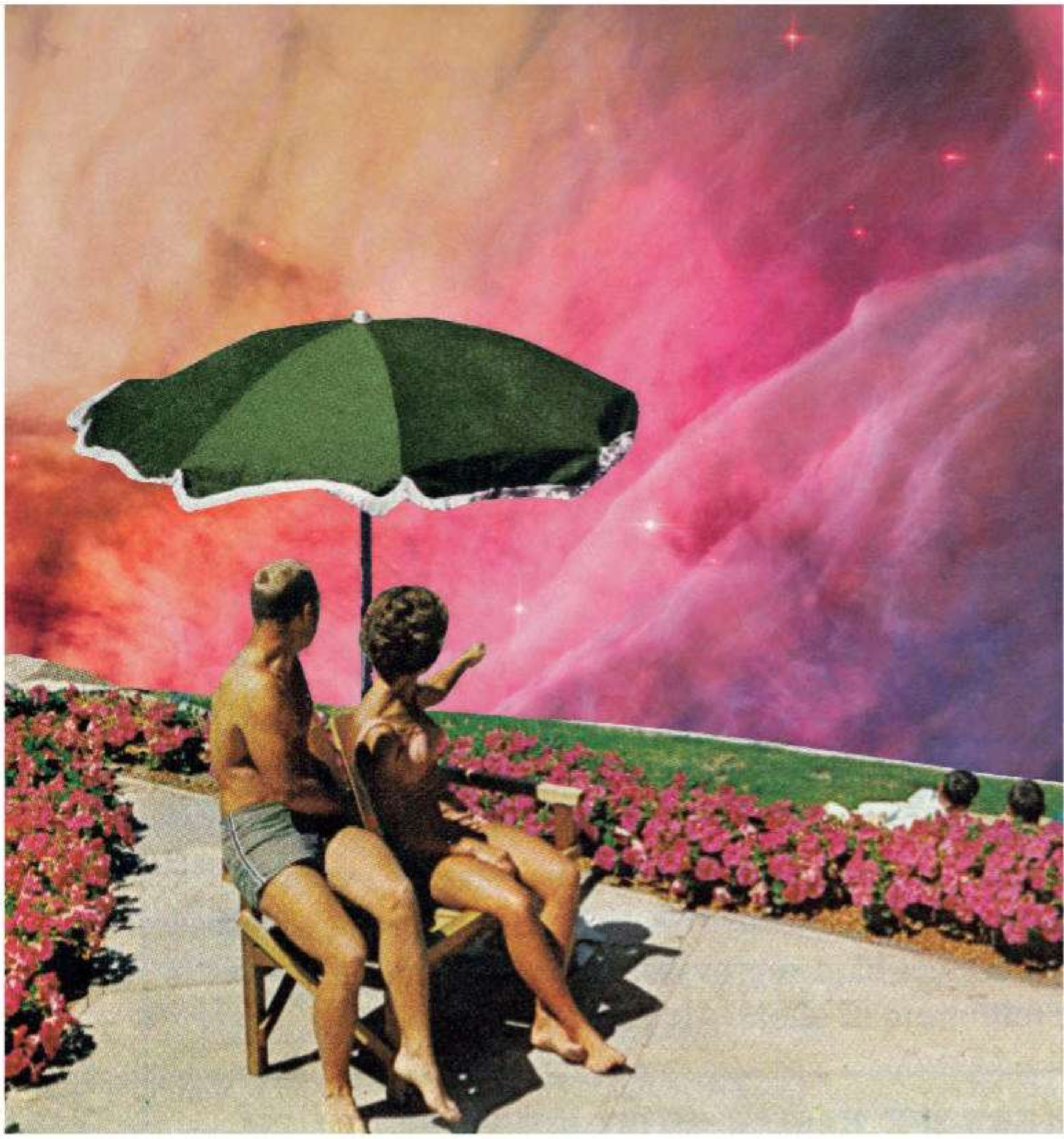
Drop in on the habitable world next door

So far, we have discovered more than 5000 exoplanets orbiting other stars in our galaxy. But there are hundreds of billions more worlds still to find – an average of roughly one per star in the Milky Way.

If we could visit any of these, we would surely want to choose an exoplanet that has a good chance of harbouring life. The trouble is that we don't know whether life can emerge in conditions beyond those on Earth, nor the spectrum of environments that can arise when planetary systems form. So the safest bet is a planet that looks something like ours.

Over the past year, the James Webb Space Telescope (JWST) has found tantalising signs of carbon dioxide, methane and water vapour in far-off exoplanet atmospheres. But it is a planet much closer to home that I would plump for: Proxima Centauri b, which orbits the closest star to the sun.

We still don't know what the conditions ›



are like on the surface of this world. Its diminutive parent star is a red dwarf that has a mass only an eighth of the sun's and is nearly a thousand times dimmer. This is fortunate, as a sun-like star would roast this closely orbiting planet to a crisp. But it is possible that Proxima Centauri b has the perfect conditions for life.

Its natural "equilibrium temperature" is -39°C, based on the energy output of its sun. If it has the right kind of atmosphere, however, a greenhouse effect could raise this to something friendlier to life. Stopping here, we find out for sure with a close-up look at its atmosphere. Depending on the composition of its air, Proxima Centauri b could be anything from a warm ocean world to a frozen ball of ice. (And if you are wondering about the power of an atmosphere to shift planetary conditions, Earth's equilibrium temperature is around -20°C (-1°F), and it is perfectly habitable thanks to the gases that blanket it – for now, at least.)

Even a glimpse of clouds or oceans would suggest the possibility of life on this alien world. But even if it is barren, I can at least promise you the Milky Way's most spectacular sunset. Proxima Centauri b orbits its parent star every 11 days and is tidally locked, meaning that the same side of this world always faces inwards – much like one side of the moon always faces Earth. One side of the planet experiences perpetual daytime, while the opposite side is trapped in eternal night. Between the two is its twilight strip, known as the "terminator" zone. Here, fierce winds rush from the searing hot to freezing cold areas. If we can brave it, we will see a truly alien spectacle: a sunset hanging forever in the sky.

Betelgeuse

For a spot of supernova gazing, if we're lucky

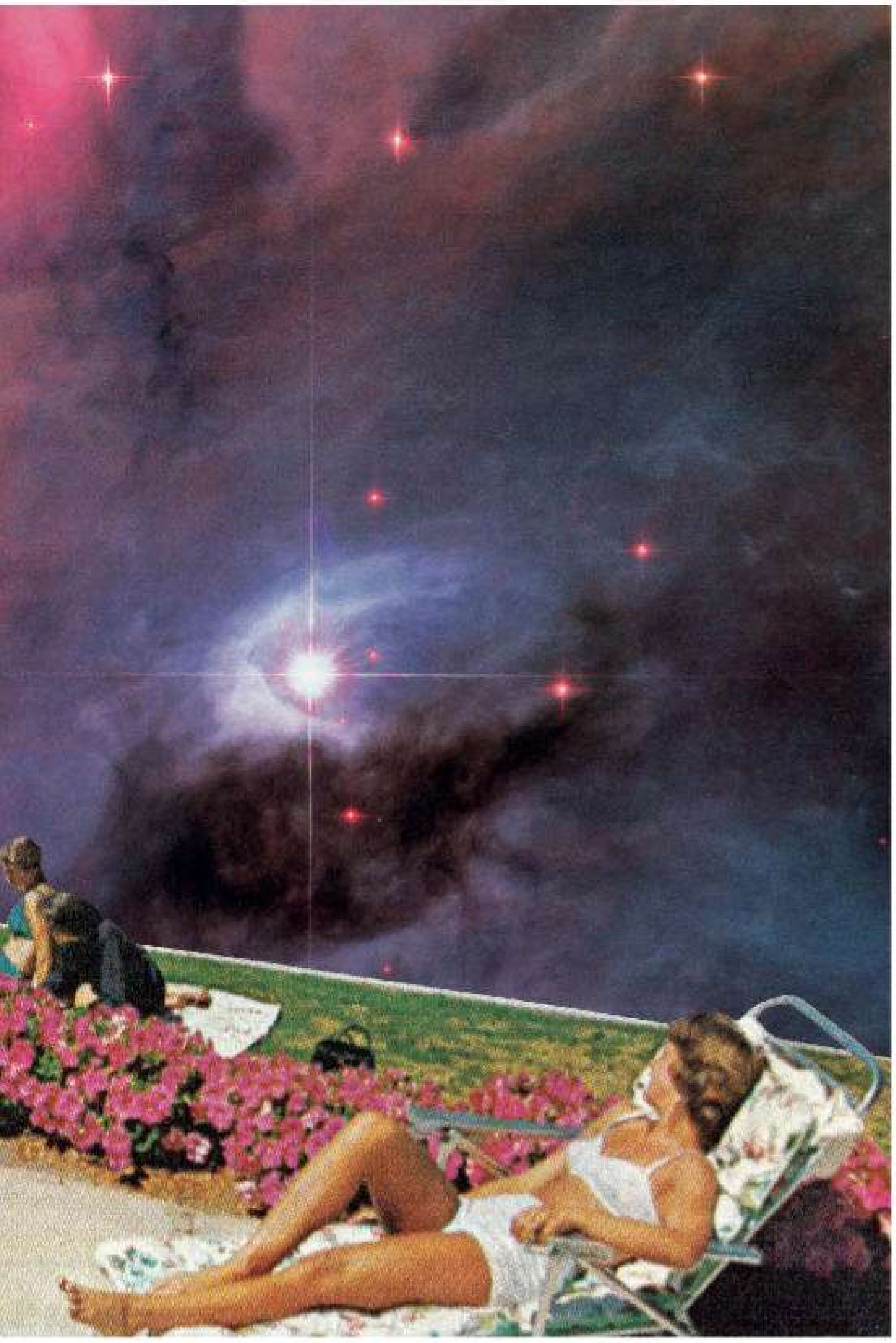
Our next destination is an enormous star, swollen with age and 100,000 times more luminous than the sun. Many of us will have seen it at one time or another, glowering deep red in the cold winter sky, sitting in the armpit of the constellation Orion. And it happens to be intriguingly unstable, which suggests it could explode as a supernova at any moment.

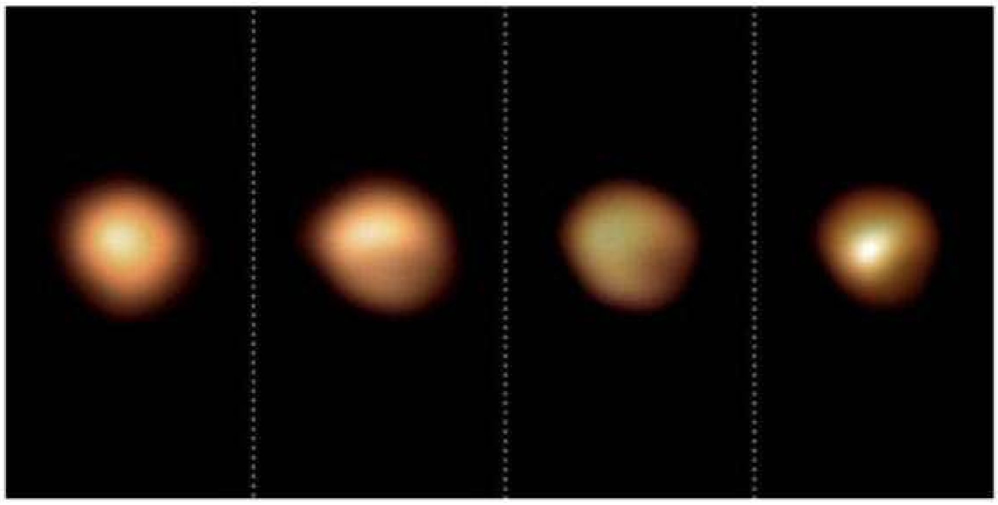
This stellar titan, known as Betelgeuse, is so massive you could fit our sun inside it hundreds of millions of times over. If it were at the centre of our solar system, it would swallow Mercury, Venus, Earth and Mars, and would come close to engulfing Jupiter too. It is so big partly because it was born large, but mostly because it has reached the final stages of its life and has expanded to become a red supergiant. Having run out of the hydrogen that sustains the nuclear fire in our sun, Betelgeuse is burning helium. The fusing of helium nuclei releases much more energy than hydrogen nuclei fusing, puffing the star up from the inside.

This is what suggests the end is nigh. There is typically only enough helium to support a star for a couple of million years. Once it is gone, the star frantically burns through whatever heavier elements are left, like a desperate ship's captain tearing up the floorboards to stoke the furnace. The star can burn carbon for a few hundred years, then oxygen for six months. It will spend one final day burning silicon into iron before fusion stops altogether.

At that point, the weight of the star collapses inwards under gravity. As the outer matter plummets towards the centre, it accelerates

> **"Light around the magnetar is refracted into a great cosmic hall of mirrors"**





ESO/M. MONTARGÈS ET AL.

Betelgeuse's pulsations may herald an imminent supernova

to a decent fraction of the speed of light. Then it crashes into the dense star core, bouncing back as a shock wave that outshines a billion stars. This is a supernova explosion.

For years, astronomers have kept a close eye on Betelgeuse, hoping to find out how far it has progressed along this path – and how long we will have to wait for its explosive end. Earlier this year, astronomers modelled how Betelgeuse pulsates, becoming visibly dimmer and brighter in the sky. From this, they reckon the star is in the late stages of carbon burning, meaning the explosion is due within centuries. Other astronomers argue that the dimming is caused by obscuring clouds of dusty material ejected by the dying star. In that case, Betelgeuse may still have hundreds of millennia left.

A flyby would tell us what is really going on. We may even land ourselves a front-row seat for one of the most spectacular firework displays in the cosmos, with waves of colour rolling off the star's outer layers in anticipation of the searing final display. Just make sure your travel insurance is up to date, as supernova explosions are incredibly violent. Even if we were to watch from Earth, when Betelgeuse finally lets loose, it will shine almost as bright as the full moon for weeks on end.

Magnetar SGR 1935+2154

See the source of strange signals from deep space

Fast radio bursts (FRBs) have long baffled astronomers. In 2007, an extraordinarily quick blip of radio waves, 10 times shorter than a lightning strike, was uncovered in archival data from a telescope in Australia. The signal showed signs of a long journey too. The way the wave frequencies were dispersed suggested this burst had travelled more than 3 billion light years before reaching Earth.

Intrigued, astronomers sought out more of these mysterious events. By trawling through old radio telescope records, and by looking in the right place at the right time, they detected dozens of new signals. But no one could make sense of what was causing them. One burst, in 2012, went off 10 times in two months before falling silent. Then, in 2018, it chirped 21 times in a single hour. Some FRBs cried out once then disappeared forever.

All FRBs seemed to come from deepest space, far beyond the Milky Way, which made them particularly tricky to study. But in 2020, astronomers picked up an FRB inside our galaxy for the first time. Excitingly, the burst came from a known object: magnetar SGR 1935+2154, which is the next stop on our tour.

Astronomers are still getting to grips with magnetars. We know these extreme objects start as the remnants of supernovae explosions: as a giant star collapses and goes supernova, it crushes particles together into an incredibly dense, spinning ball just a few kilometres across, called a neutron star. These are so dense that a teaspoonful of neutron star matter would weigh roughly 10 million tonnes.

Neutron stars become magnetars when their interior somehow whips up the strongest magnetic fields in the universe – a million billion times more powerful than Earth's field. So tourists should be wary: even a thousand kilometres away from SGR 1935+2154, the intense magnetism would shred your atoms into a fine mist. From a safe distance, though, we will be treated to strange, shimmering patterns of light that coruscate across the surface. The magnetar warps space-time around it so that light travelling nearby will be refracted into a great cosmic hall of mirrors.

A closer look might even help us figure out how magnetars produce FRBs. In January, SGR 1935+2154 suddenly calmed its ferocious › spinning, known as a "spin-down glitch", before releasing three new radio bursts. One idea posits that winds of charged particles flood out of the magnetar's north and south poles, smashing into the magnetic fields and triggering emissions. Another idea is that FRBs result from gargantuan tremors in the magnetar's crust called "starquakes". If we got very lucky with the timing, we might be able to see for ourselves.

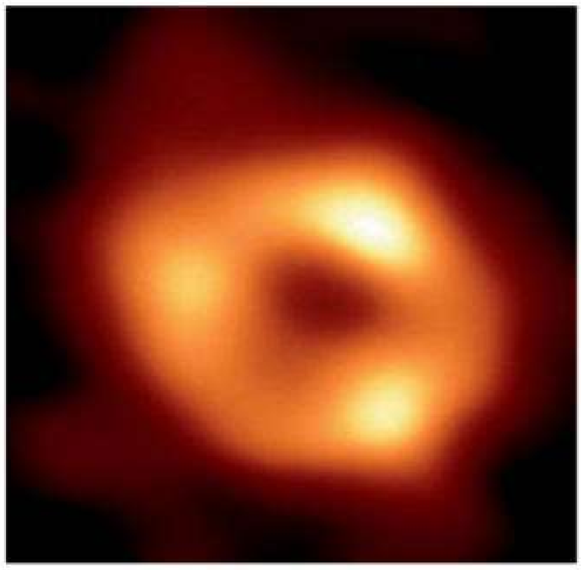
Sagittarius A*

Gawp at a monstrous black hole

No tour of the galaxy would be complete without a visit to the supermassive black hole at the heart of the Milky Way, where we are guaranteed a mesmerising light show – and we might even spot crucial hints about the true nature of space-time.

Radio engineer Karl Jansky picked up the first hints of Sagittarius A*, as it is known, almost a century ago while he was investigating the static that plagued early radio communications. But astronomers only confirmed beyond doubt that there is a giant black hole at the centre of our galaxy in 1998. By precisely observing how stars orbit the galactic centre, they proved the existence of a body with a mass some 4 million times that of the sun. Telescope images show stars locked in orbit around what appears to be nothing at all.

Last year, astronomers even captured an image of this black hole. The team behind the Event Horizon Telescope connected observatories all around Earth to build what is in essence a telescope the size of the planet. The resulting fuzzy orange doughnut image, which made headlines all over the world, reveals the accretion disc around Sagittarius A*: a ring of doomed gas and dust, with a diameter smaller than the orbit of Mercury, swirling around a cosmic plughole.



EHT COLLABORATION

ESO

Hot debris illuminates the black hole at the centre of the Milky Way (above)

The Sculptor dwarf galaxy contains some of the oldest stars in the universe (left)

The telescope has the highest resolution ever achieved by astronomers. Observing Sagittarius A* is like reading the lettering on a coin in New York using a telescope in London. But there are some questions physicists will only be able to answer by getting a closer look.

The extreme environments in and around black holes have long been a playground for theorists testing our best understanding of fundamental physics. Currently, we have two incompatible theories that explain how the universe works. General relativity works on large scales and with large masses, describing gravity's effects in the cosmos. Quantum mechanics, on the other hand, is the science of the very small. To find out what happens when these theories collide, and to try to unify them, you need something that is both very heavy and small. Nothing like this exists in the lab. A black hole, though, is perfect.

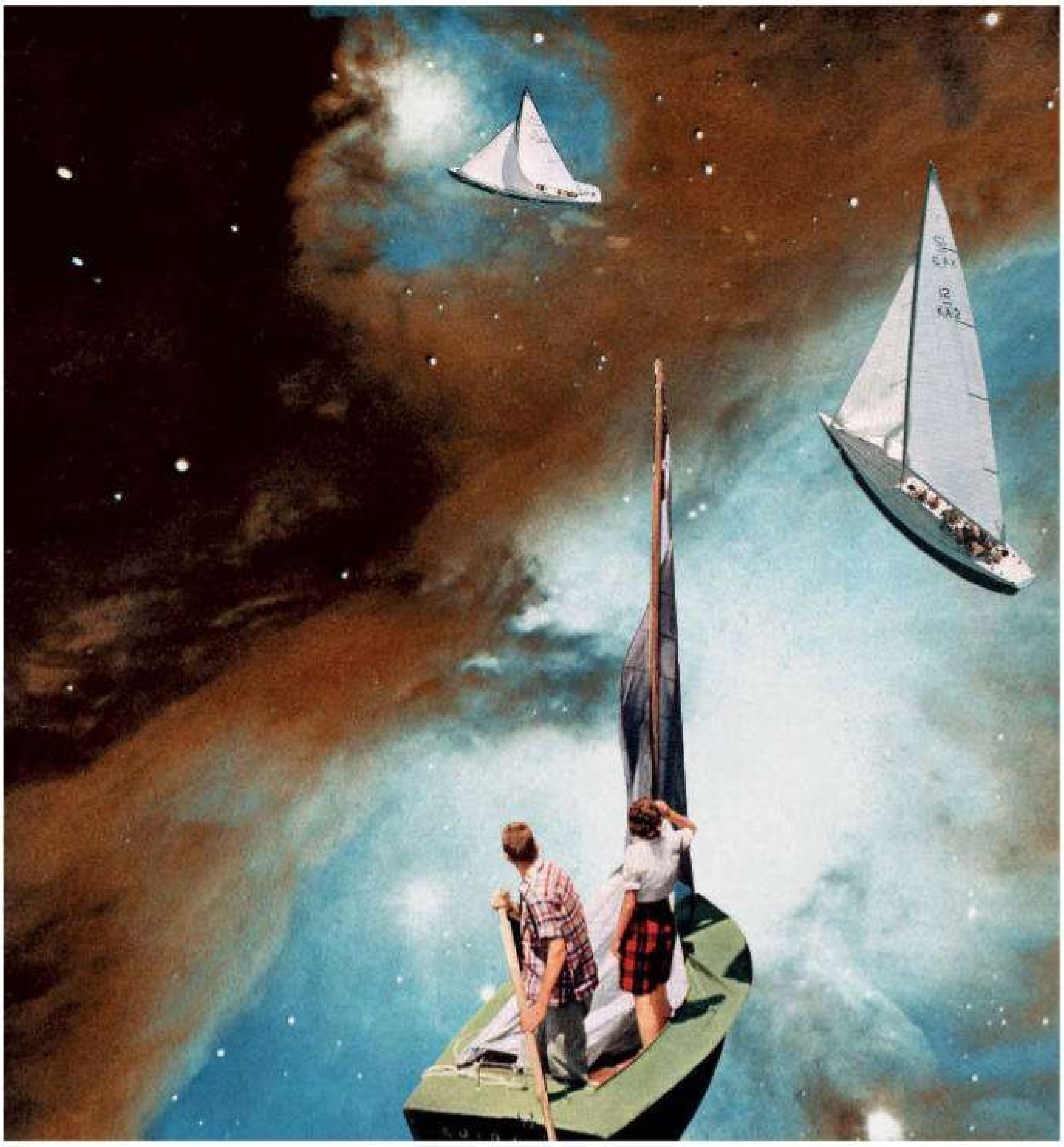
The edge of a black hole, beyond which not even light can escape, is called the "event horizon". Careful experiments observing how matter accelerates at this cosmic precipice could provide evidence for various theories of quantum gravity, each of which says that space-time can be broken down into tiny quantum packets in different ways. Studying the surrounding accretion disc, meanwhile, would teach us a lot about black hole behaviour. When gas spirals inwards, it can ignite fountains of radiation upwards and outwards at close to the speed of light. But as the cores of black holes are usually shrouded in dust, we have little idea how this happens.

Regardless of what we might learn, we would still have the light show. Anything crossing the event horizon of Sagittarius A* is swallowed by the black hole, but just outside of this perimeter, the extreme warping of space-time means light can be pulled into endless circles. Light coming from all the stars in the Milky Way and beyond is trapped in this layer, known as the "photon sphere". Here, then, is our chance to see a truly infinite cosmic movie.

PSR J1719–1438 b

Goggle at a diamond planet

When is a planet not a planet? The answer to this riddle lies around 4000 light years from Earth, in one of the strangest solar systems we know of. At the centre sits a rapidly spinning neutron star called a pulsar, which emits



powerful beams of radiation like a lighthouse. Around this star orbits an ambiguous planet, J1719–1438 b, which itself was once a star.

By observing the dance of this odd couple, astronomers calculated that this world must be incredibly dense – four times denser than Earth, which is the densest planet in our solar system. The only way to explain this is if J1719–1438 b is mostly composed of crystalline carbon. In other words, what we have here is a giant diamond world.

Astronomers suspect it was made by stripping a star. Small stars like the sun end their life as compact spheres of carbon and oxygen called white dwarfs. The pulsar's radiation beams may have peeled away the outer layers of this stellar remnant, leaving the crystal core glinting in the vacuum of space.

Now coated in interstellar dust and baked by the pulsar's radiation, the surface of this cosmic jewel may well be blackened. We can only know for sure by heading there. We may even find that PSR J1719–1438 b isn't a diamond planet at all, but a lump of exotic "quark matter". This weird phase of matter could occur when particles are forced even closer together than those in a neutron star. The stew of fundamental quarks that results is still hypothetical, but some theorists reckon it sloshes about like a fluid with zero viscosity.

Sculptor dwarf galaxy

Witness a proxy for the early universe

The Sculptor dwarf galaxy appears as a gossamer of galactic fluff on the outskirts of the Milky Way – taking us to the furthest and final stop on our tour. It is well worth the 300,000-light year trip, as our galactic neighbour is a time capsule from the universe's deep past.

Thirteen and a half billion years ago, after the fireball of the big bang, the universe was dull, featureless and devoid of light. The dark ages, as they are known, lasted hundreds of millions of years until, out of the primordial gas, the first stars sparked into life.

These "Population III" stars are very different to those in our galaxy today. Since the dark ages, many generations of stars have lived and died. The heavier elements forged in the cores of stars – such as oxygen, carbon and iron – became part of the next generation, forever altering their chemistry and characteristics. But the first stars contained none of these contaminants. Pristine Population III stars were made out of the elements created in the moments after the big bang: hydrogen, helium and a sprinkling of lithium. As a result, these first stars were far bigger and hotter.

Population III stars are pivotal to the evolution of the universe. Exactly how big, and how abundant, these were can reveal clues about how the first galaxies formed and grew – so astronomers understandably want to find them. JWST has found hints of them. But looking that far back in time also means looking far away, which makes for low-resolution images.

This is where the Sculptor dwarf galaxy comes in. Most of its slow-burning stars are ancient, around 12 billion years old, which isn't far off the age of the first stars. This makes them emissaries from the early universe. And in 2021, astronomers found one particular star, called AS0039, so deficient in heavier elements that it seems to be a direct descendent of a Population III star, born from the material produced when that primordial star died. Taking a good telescope and studying AS0039 up close would help us to fathom these primeval cosmic furnaces.

The Sculptor dwarf galaxy also happens to be the perfect place to finish our tour. Even with the naked eye, its position would afford you a unique vista of the great spiral of the Milky Way splashed across the sky. Where holiday snaps are concerned, it doesn't get much better than that. ■

Matthew Bothwell is the public astronomer at the University of Cambridge, UK

The back pages

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Stargazing at home

Get a bird's eye view

The constellation Aquila, the eagle, is home to stunning deep-sky objects. Here's how to spot it, says **Abigail Beall**

Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy*. Follow her @abbybeall

What you need

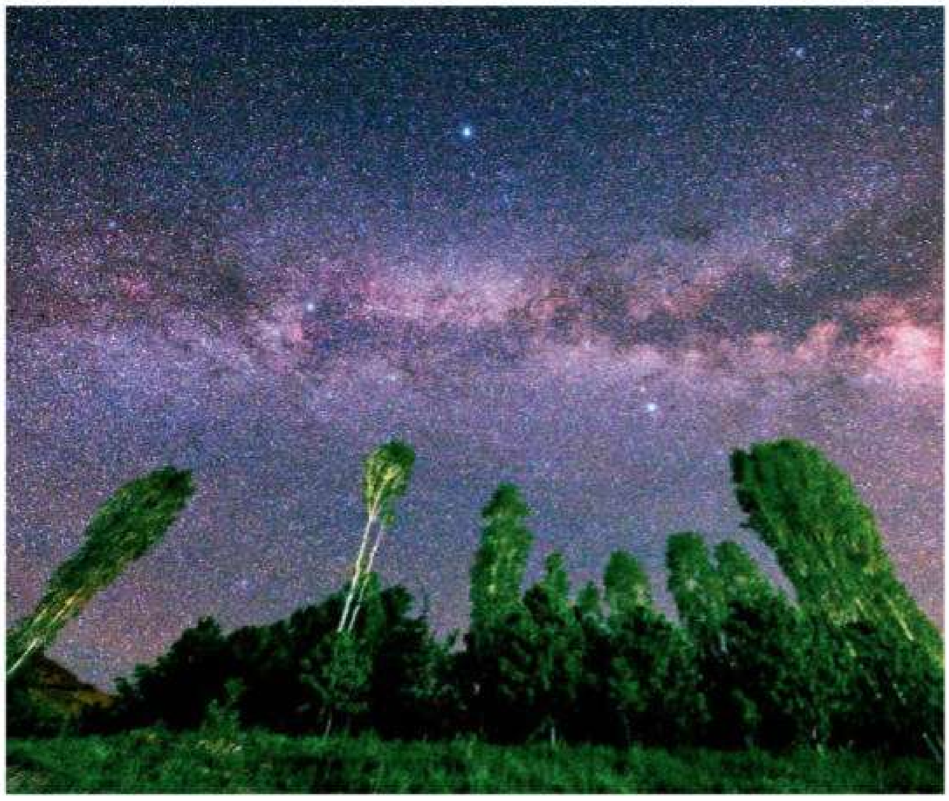
A small telescope (optional)

LAST month, we looked for the constellation of Cygnus, the swan. I like to think of our next target, the constellation of Aquila, the eagle, as a little sister to Cygnus: it is also named after a bird, has a similar cross shape and sits next to Cygnus in the sky. Aquila was the bird that carried thunderbolts for Zeus in Greek mythology and for Jupiter in Roman mythology.

We used the pattern of stars known as the summer triangle (pictured) to find Cygnus, and we can do the same for Aquila. The triangle is made up of three stars: Vega (at top of image), Deneb (left) and Altair (right). To spot them, look south after sunset in the northern hemisphere. Vega will be the highest of the three in the sky, with Deneb, which is in Cygnus, to its left and Altair below. In the southern hemisphere, look west. Altair will be highest, with Vega and Deneb nearest the horizon.

Altair is in Aquila and it represents the head of the eagle. Depending on where you live, the summer triangle will appear in different orientations, but Altair is recognisable because it sits furthest away from the other two stars that make up this feature.

Once you have identified the three stars of the triangle, draw an imaginary line from Vega to Altair. The rest of Aquila makes another line stretching out perpendicular to this line, in the direction away from Deneb, making the whole constellation look like a big cross.



BABAK TAFRESHI/SCIENCE PHOTO LIBRARY

Just like Cygnus, Aquila sits along the disc of the Milky Way, which means it is home to some great deep-sky objects – in other words, things that aren't just single stars or part of our solar system. A planetary nebula called NGC 6790, a globular star cluster called NGC 6760 and an open cluster called NGC 6755 are great to look for near the centre of the constellation using a small telescope.

Near the tail of Aquila, in a constellation called Scutum, sits a V-shaped open star cluster called the Wild Duck, also known as M11. Named for its resemblance to a flock of flying ducks , this feature is about 6000 light years away and is estimated to be home to up to 11,000 stars.

In between Cygnus and Aquila, there are a few tiny constellations, each containing very faint stars. You may never have heard of these: Equuleus, the little horse; Delphinus, the dolphin; Sagitta, the arrow; and Vulpecula, the little fox. They can be difficult to spot, but a stargazing app will help.

In 1983, after a few drinks, a pair of Japanese astronomers decided to send a message towards Altair in the hope that there might be intelligent life on any planet orbiting it. The message contained the words for cheers in English and Japanese, plus the chemical symbol for methanol.

We don't know of any planets around Altair, which is only about 17 light years away. Given the distance, if an alien civilisation had received the message, we could have had a reply in 2017. ▮

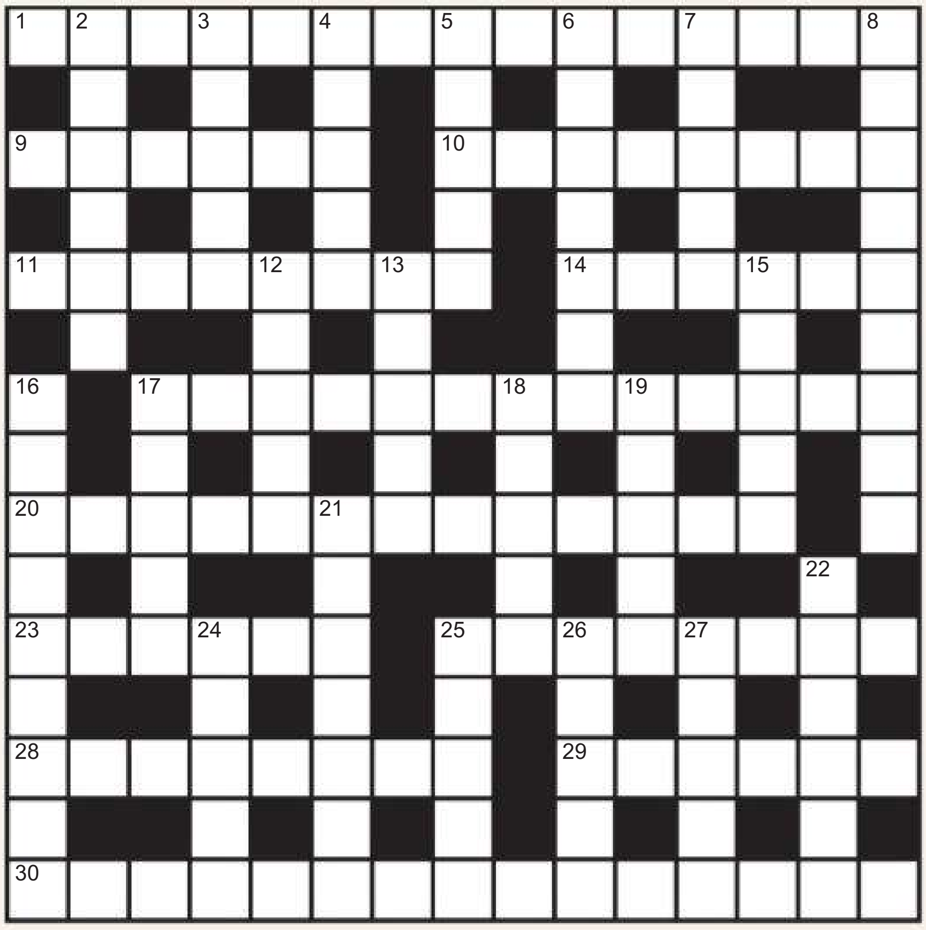
Stargazing at home appears monthly. Share your stargazing successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistStargazing

Next week

Mathematics of life

These articles are posted each week at newscientist.com/maker

Quick crossword #144 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Honorary title currently held by Martin Rees (10,5)
9 Buttocks (6)
10 Type of pendulum; city layout (8)
11 Home city of Caltech (8)
14 Eugene ___, Hungarian-US physicist (6)
17 Explosive also known as 1,2,3-trinitroxypropane (13)
20 Laid-back way of getting around? (9,4)
23 In (6)
25 Fixed bar on which wheels revolve (8)
28 Seashore events in which the intertidal zone is slowly exposed (3,5)
29 Tumour of the connective tissue (6)
30 F_{tu} (7,8)

DOWN

2 Concerning woodlands (6)
3 A net, in anatomy or engineering (5)
4 Unwanted or meaningless sound (5)
5 Molten rock (5)
6 Transport system of fixed tracks (7)
7 Toric joint (1-4)
8 Effective at great distance (4-5)
12 Statistic, say (5)
13 Running knot (5)
15 Axon bundle (5)
16 Component of a medicine that modifies other effects (9)
17 Battery type (5)
18 Rubber emulsion (5)
19 Gradient of differences within a species (5)
21 Having two modes (7)
22 Pierre de ___, author of notable marginalia (6)
24 Tiny amounts (5)
25 Extreme point in the orbit of a planet (5)
26 Primate of Madagascar (5)
27 Harmful substance (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #224

set by Bethan Ackerley

1 What name is given to the fluid that circulates in the interior of arthropods, similar to blood?

2 Who was the first woman to perform a spacewalk?

3 What is the calcified substance that covers the roots of human teeth?

4 Which of the following is the natural mineral form of lead(II) sulphide: muscovite, galena or kaolinite?

5 The BepiColumbo mission intends to primarily study which planet?

Answers on page 47

Headscratcher

set by Zoe Mensch

#244 Wheel-to-reel

Jim Ford and his daughter Jade were leaving the Old Hat Cinema Club after watching the classic silent western *Sunset At Cactus Rock*.

"What did you think?" asked Jim. "It was alright," said Jade, "but the CGI wasn't great. At the end, when the stagecoach was at top speed, none of the wheels were moving!"

"Ah," smiled Jim. "That's because those old movies were filmed at 16 frames per second." Jade's eyes glazed over as her dad launched into more western nerdery. "Those coaches were called 'four-yarders' because the circumference of the back wheels was 4 yards."

"A yard?" asked Jade. "It's an old measure, a bit shorter than a metre," said her father. "The back wheels had 24 spokes. The front wheels had 12 spokes and were three-quarters the diameter of the back wheels. On those dirt roads, they weren't very quick – Usain Bolt could have run faster."

How fast, in old-fashioned yards per second, was the stagecoach moving when its wheels appeared to be stationary?

Solution next week

High speed

We know time slows down as gravity increases, so is the speed of light in high gravity different from its speed in low gravity?

Eric Kvaalen
Les Essarts-le-Roi, France
Time doesn't necessarily slow down as gravity increases. What matters is how deep a point is in a gravitational well, which depends on how much energy it would take to get a 1-kilogram object very far away from the object producing the gravity.

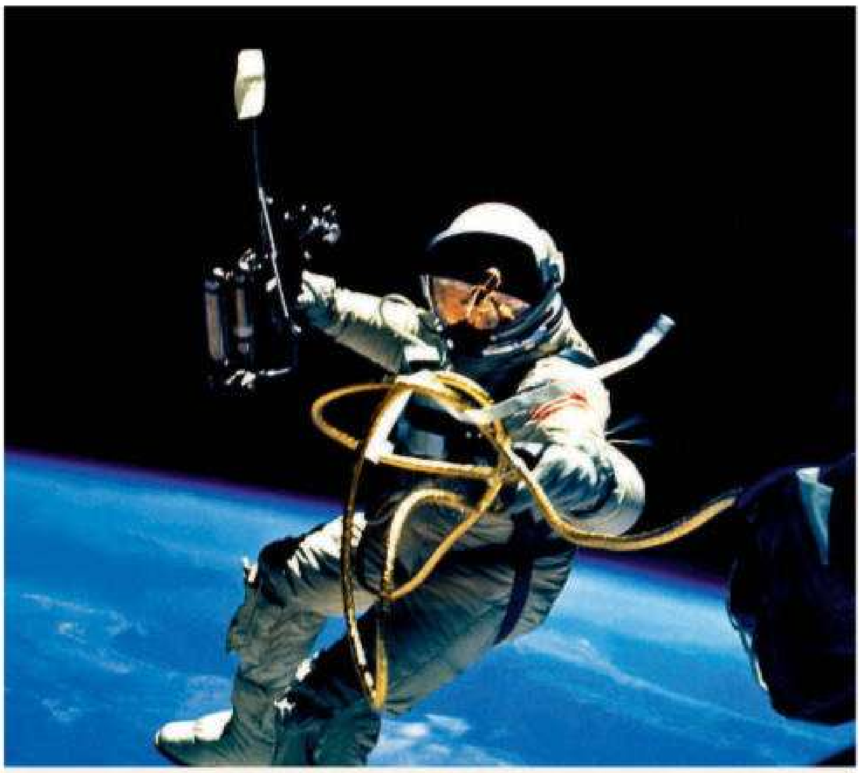
Clocks run slower at the centre of Earth than they do at its surface, even though the gravitational field there is zero. If you stand in a hole in a layer of haematite iron ore or between stacks of gold bars – both of which are made of material that is more than two-thirds the average density of Earth – your feet will experience weaker gravity than your head, but time will still go more slowly for your feet.

The speed of light as measured locally is always the same, around 300,000 kilometres per second. But if it were possible to observe where a photon or a light wave was and the light in question was moving deep in a gravity well, such as near a black hole, then, to us, it would look as though the light was moving slower than 300,000 km/s.

> "If we watch an object falling towards a black hole, it would appear to us to go slower, and for us would never get to the event horizon"

In our frame of reference, a photon emerging from near the event horizon of a black hole takes a very long time to get away from the black hole. By the same token, if we watch an object falling towards a black hole, it appears to us to go slower and slower and, from our point of view, it would never reach the event horizon.

For this reason, the "black holes" that we see in the heavens aren't yet really black holes, because the material, from our point of view, never actually finishes collapsing to make one.


ART DIRECTORS & TRIP/ALAMY

What would really happen to a person's body if they were in space without a suit?

This week's new questions

Lost in space **In films, people in space without a suit are often depicted as being very cold, with their bodies intact. What would really happen?** ***Penny McInnes**, Okehampton, Devon, UK*

Squeezing out **What is the shortest space a parked car can get out of? Or a parking car can get into?** ***Toby Ebert**, Ilfracombe, Devon, UK*

Ron Dippold
San Diego, California, US
It can be *apparently* slower if you are far away – it's all relative!

First, the apparent speed of light varies in different mediums. It is about 30 per cent slower in water than in a vacuum because the light keeps getting absorbed and re-emitted. The gold standard is the speed of light in a vacuum, *c*, which is conveniently close to 300,000 km/s. So let's assume we mean a vacuum from here on.

Someone in high gravity measuring the speed of light in a vacuum near them will find it is still *c*, unchanged. And someone using the same set-up in low gravity will also measure *c* as unchanged. So the answer is no, right?

Well, let's say you have someone far away from the event horizon of the black hole in the centre of our galaxy, Sagittarius A*. This is relatively low gravity, so they are our "low-gravity observer". They are watching an experiment near the event horizon of Sagittarius A*, where a laser is sent all the way around the event horizon, with the help of repeaters, through a tube of thin gas that lights up when the laser goes through. This is definitely high gravity, so someone surviving here (an AI?) is our "high-gravity observer".

Sagittarius A* is 160 million km in circumference, so our high-gravity observer (near the laser) would indeed see it takes about 10 minutes for light to circle it – *c* is unchanged. However, the low-gravity observer watching the tube light up from far away would see it take much longer. If the laser and tube were about 15 million km from the event horizon and the low-gravity observer were 200 million km away, the low-gravity observer would see it takes about 15 minutes for the laser to go around. High-gravity light looks much slower to the low -gravity observer.

People argue a lot about what this means. Again, it all depends on what assumptions you make and whose point of view you want to take. Relativity considers time as a fourth dimension (it is "space-time", after all) and high gravity warps space-time by something known as the Schwarzschild metric. The low-gravity observer can calculate that the speed of light in that warped four-dimensional high-gravity space-time is the same as in their four-dimensional low-gravity space-time when correcting for that warping.

But it is entirely fair to say that for the low-gravity person, the speed of light in high gravity appears to be relatively slower. That is why it is the theory of relativity.

David Hyde
Henley-on-Thames, Oxfordshire, UK
No, light always travels at a constant speed, *c*. Light has a dual nature, behaving both as a wave and as a particle called a photon, which is massless and therefore isn't influenced by gravity.

Herman D'Hondt
Sydney, Australia
The fact that the speed of light is constant is one of the cornerstones of Albert Einstein's theory of special relativity.

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Tom Gauld
for New Scientist

ONCE I REALISED THAT I GET MY BEST IDEAS IN THE BATH, ON MY COMMUTE OR WHEN I'M WALKING THE DOG, IT SEEMED ONLY LOGICAL TO COMBINE THE THREE.

In 1887, Albert A. Michelson and Edward W. Morley conducted an experiment in which they tried to measure the difference in the speed of light as Earth moved through the hypothetical "aether". As our planet moved around the sun, the different directions of its travel through the aether ought to have affected the measured speed of light. They found no difference whatsoever, and this has been confirmed many times since then.

In his 1905 paper on special relativity, Einstein used this fact to tell us why time and length must change depending on the speed of the observer. Ten years later, in his theory of general relativity, he used the same fact to explain why gravity affects our measurement of time. General relativity has been confirmed over and over in the past 100 years. No evidence has ever been found that contradicts it.

By extension, it follows that no evidence has ever been found for any change in the speed of light, whether that is by speed, gravity or any other factor affecting the measurements.

> **"Some 88 million years ago, India and the island of Madagascar were neighbours in an ancient landmass called Gondwana"**

Straight to the point

Why is the east coast of Madagascar so straight?

David Bortin
Whittier, California, US
It was discovered about 10 years ago that, some 88 million years prior, the subcontinent of India and the island of Madagascar were neighbours in the ancient landmass called Gondwana. But plate tectonics makes for strange bedfellows, and it gave India the wanderlust to split off and elope with southern Asia, some 4800 km to the north.

The rapid split produced what is described as a "scraping" action that left Madagascar's east and (to a lesser, but still noticeable extent) India's south-western shoreline remarkably straight.

The future remains to be seen by our successors billions of years from now, but it has been suggested by some that Madagascar might follow India. More likely is the prospect of Madagascar's fragmentation.

Mustapa Osman
Singapore
The east coast of Madagascar is straighter partly because of consistent ocean currents and wave action from the Indian Ocean. Over millions of years, these forces have eroded the coastline in a more uniform way, making it appear straighter.

Unlike the west coast, which has more bays and river mouths that create a jagged appearance, the east coast of the country has fewer of these features, contributing to its straight look.

David Clarke
Seaford, East Sussex, UK
Madagascar is an example of the early work of Slartibartfast before he got into designing fjords. ▮

Answers

Quick quiz #224
Answers

1 Haemolymph
2 Svetlana Savitskaya
3 Cementum
4 Galena
5 Mercury

Cryptic crossword #120 *Answers*

ACROSS 1 Bearing, **5** China, **8** Manifesto, **9** Tic, **10** Stein, **12** Ripcord, **13** Alpha and omega, **15** Thorium, **17** Vatic, **19** Orb, **20** Eucalypti, **22** Heart, **23** Lie back

DOWN 1 Bombs, **2** Ann, **3** Infanta, **4** Gastronomical, **5** Croup, **6** Introvert, **7** Arcadia, **11** Euphorbia, **13** Antioch, **14** Orville, **16** Inert, **18** Crick, **21** Pea

#243 Emmental arithmetic
Solution

For two three-digit numbers to clash, they must only contain digits that are still valid when a ticket is turned upside down. 0, 1, 2, 5 and 8 all read the same in this case, while 6 becomes 9 and vice versa.

To get two numbers that are very close, the hundreds digit needs to be the same or at most different by 1. Differing by 1 could give us numbers such as 081 and 180 which differ by 99. We can do better by using a 9 in the middle for 091 and 160, differing by just 69. But the closest match is by making the hundreds digit and the units digit the same and using a 6 or 9 in the middle, such as 868 and 898, giving a difference of 30. As long as there are fewer than 30 customers at a time, there won't be a clash.

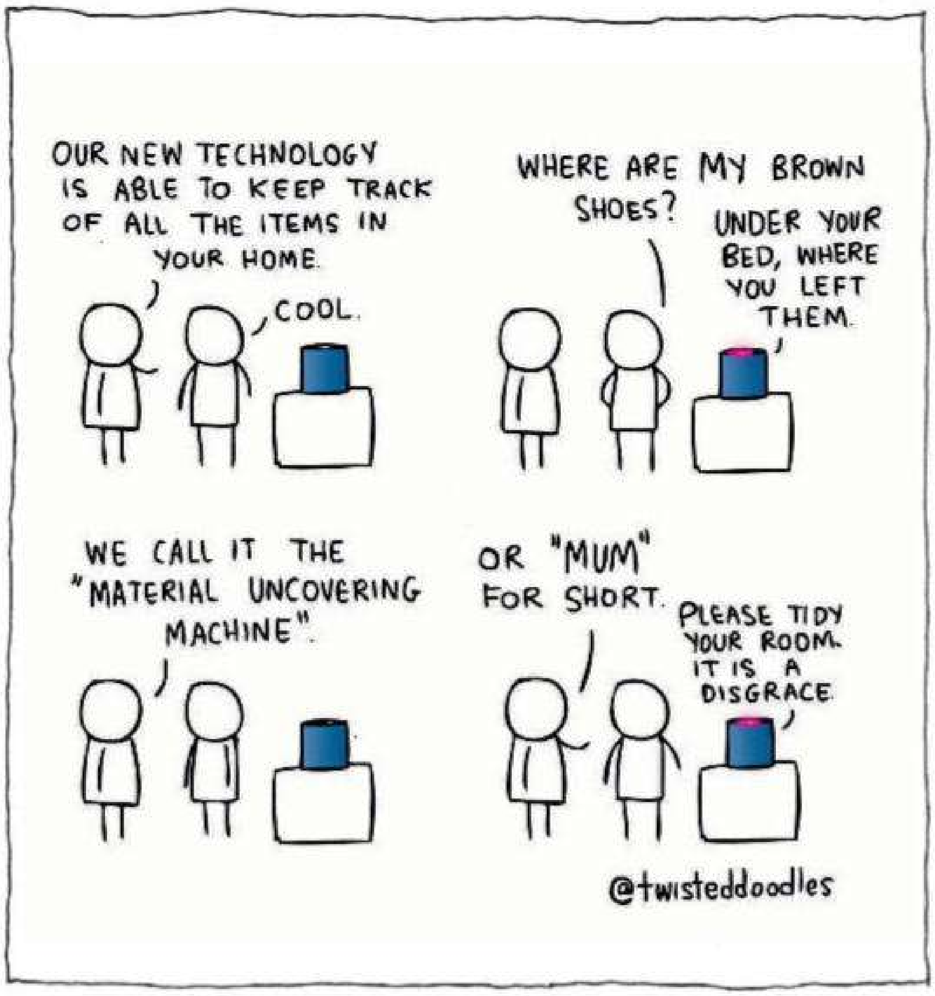
A frothy matter

A report called "Beer foam is a carrier of aroma" may be the crushing blow beer foam aroma sceptics – if there are any – feared.

Hirotaka Kaneda at Kyushu Sangyo University in Japan and colleagues make their foam aroma-carrier claim in the *Journal of the American Society of Brewing Chemists*. They explain that it isn't easy to measure the aroma in beer foam because it "undergoes continuous cycles of bubbling and collapsing". The researchers overcame this difficulty.

Their paper also states that "beer foam is extremely important not only for its appearance but also for its deliciousness" – which, if true, may be the crushing blow that beer foam deliciousness sceptics – if there are any – feared.

Twisteddoodles *for New Scientist*


OUR NEW TECHNOLOGY IS ABLE TO KEEP TRACK OF ALL THE ITEMS IN YOUR HOME.
COOL.
WHERE ARE MY BROWN SHOES?
UNDER YOUR BED, WHERE YOU LEFT THEM.
WE CALL IT THE "MATERIAL UNCOVERING MACHINE".
OR "MUM" FOR SHORT.
PLEASE TIDY YOUR ROOM. IT IS A DISGRACE
@twisteddoodles

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Consideration of items sent in the post will be delayed

Hierarchy of dog needs

For the past four-fifths of a century, human psychologists have been accepting, debating or rejecting Abraham Maslow's idea about a "hierarchy of needs".

Maslow created a little list of things that seem to motivate and drive a person's thoughts and actions. In a 1943 paper called "A theory of human motivation", he specified what he said was "a hierarchy of relative prepotency" of five things he called "motivations": "physiological, safety, love, esteem, and self-actualization". Maslow's list of universal human needs motivated several generations of psychologists to write thousands of papers. And perhaps to take pride in using the non-vernacular phrase "self-actualization".

Over decades, the list – and its usefulness to scholars – evolved. Now, in 2023, it has become superhuman. Karen Griffin, Saskia Arndt and Claudia Vinke at Utrecht University in the Netherlands wrote a study called "The adaptation of Maslow's hierarchy of needs to the hierarchy of dogs' needs using a consensus building approach". As if the title isn't clear enough, the paper says: "A well-established model of human needs (Maslow's Hierarchy of Needs) was borrowed from the social sciences and adapted to be relevant to dogs."

But within the community of humans who professionally care for dogs, seeds of doubt – doubt about the necessity of Maslow's "needs" – had already sprouted. "Time to reassess Maslow's hierarchy of needs," wrote Sarah Page-Jones in *Vet Record* in 2022, about veterinary professionals' need "to adopt a healthier approach to breathing, eating, drinking and sleeping".

Page-Jones, a fellow of the Netherlands-based Center for Evidence-Based Management, states exactly what she thinks Maslow's "needs" need: "we must remember that Maslow's 80-year-old theory lacks an evidence base and that many of us are lucky to possess the resources to meet those universal human needs."

Hierarchy of dino needs

Recently, Maslow's hierarchy of needs also lent itself to the scholarly appraisal of two movies. Tidtaya Puteri Larasanty made it the heart of her 2023 dissertation at Diponegoro University, Indonesia. She called it "Hierarchy of needs of the main character in *The Good Dinosaur* (2015) movie".

Larasanty writes that the main character, an apatosaurus named Arlo, "successfully fulfils… physiological needs, safety needs, love and belongingness needs, esteem needs, and self-actualization needs. This success cannot be separated from the help of another character, Spot, who helps Arlo in fulfilling his hierarchy of needs."

A year earlier, Nurlela Nurlela, M. Natsir and Setya Ariani at Mulawarman University, also in Indonesia, published a paper in the *Jurnal Ilmu Budaya (Journal of Cultural Studies)*. The title was "Maslow's hierarchy of human needs of the main character in *Abraham Lincoln Vampire Hunter* film (2012)". Anyone familiar with the film – or Abraham Lincoln or vampires or vampire hunters – will presumably gain insight from the study's conclusion: Abraham's character fulfilled all five stages of the hierarchy "such as physiological needs, the belongingness, esteem needs, safety needs. But he struggles to fulfil his self-actualization needs because to [achieve] his dream, he needs to do some [work] such as hunting the vampires."

Superpowerlessness

David Collins demonstrates a classic technique of scientific inquiry: look at the opposite of something that is already known.

He studied Feedback's collection of trivial superpowers and says: "I was becoming depressed at the astonishing range of superpowers claimed by *New Scientist* readers. So I offer my own contribution. I have no sense of direction. I don't mean being unable to tell where north is: I cannot point to where I have just been. Frequent visits to client offices are a special problem. They ask me where I parked: I have no idea where to point. I cannot find my way back to reception. Commuting by car from Croydon to Berkhamsted, a journey of about 60 miles across London, pre M25 [motorway], was really difficult. It took me several months to discover I was coming and going by two different routes. I am now retired, but still cannot point to the railway station from my favourite coffee shop."

David has thus identified a new category of human attributes, a counterpart to trivial superpowers. We shall call them trivial superpowerlessnesses. ▮

Marc Abrahams

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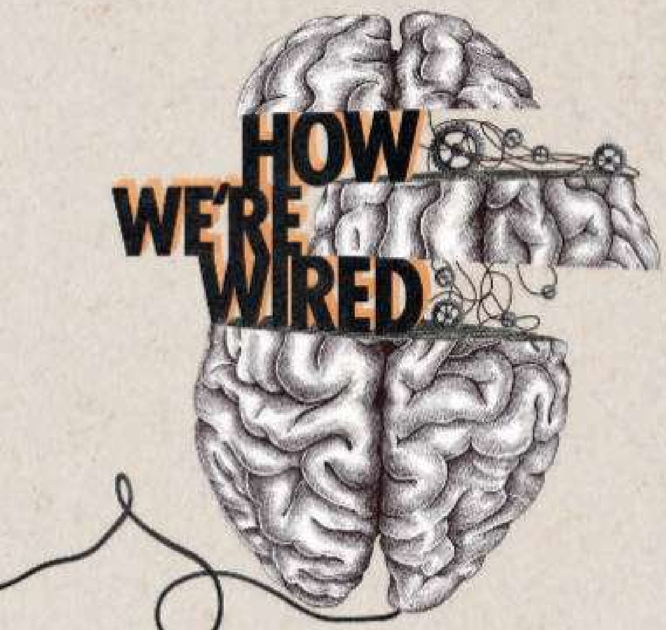

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